METALLURGIA

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Government Stockpiling

THE requirements of the defence programme have caused the Government to proceed with emergency plans for acquiring adequate stocks of materials at present in short supply. Some idea of the steps contemplated to build up stocks is indicated by a supplementary estimate recently presented to Parliament by the civil departments. The Ministry of Supply is to spend £7·7 million on some unspecified materials for strategic reserves. This will doubtless refer to the non-ferrous metals, copper, zinc, lead, tin and aluminium, which have been in the news of late as being in short supply, but will also include tungsten, cobalt, manganese, sulphur and several other important materials, imports of which might be impossible or extremely difficult, at least during the early period, should there be an outbreak of war. The same Ministry is also seeking permission to buy machine tools, accessories and other production equipment needed immediately for armament manufacture, for which purpose the estimates include the sum of £59·5 million. The intention is to set up a pool of machine tools which can be used either in Government establishments, or in private works engaged on Government contracts, under schemes of capital assistance. The Ministry states that the money is required in order that advance payments can be made to foreign suppliers.

The Minister of Food is to spend £3 million on essential foodstuffs which might become scarce in an emergency. The amount sought is to cover the costs of transport and storage. No details are given of an expenditure of £2 million sought by the Board of Trade for the purchase and storage of strategic reserves. The sum of £0·5 million is to be provided in grassland fertiliser subsidies to help to improve meat production and £1·1 million is to be set aside for grants in respect of petrol-driven machines to assist in mechanisation of farms. It will be appreciated that these supplementary estimates are only intended to cover the remaining period of the present financial year which ends on March 31.

It is unfortunate that stocks in this country have been permitted to fall to such a dangerous level. Since the conclusion of hostilities in 1945 one emergency has followed another with amazing regularity, due largely to a cheese-paring policy adopted in an effort to overcome the unfavourable balance of payments that existed. In pursuing this policy imports of food and materials have been ruthlessly cut down and, in consequence, a hand-to-mouth existence has prevailed, which has prevented the country possessing that resilience to fluctuating conditions and caused each succeeding difficulty to become an emergency. It is true that by increasing efforts and reducing imports a favourable balance of payments has been announced for 1950, but it does seem that this has been accomplished, to a considerable degree, at the expense of food and material supplies, and, as a result, the needs of the defence programme have caused the Government to proceed with emergency plans for acquiring strategic material. Had the normal procedure been carried out of maintaining adequate supplies in the country to meet fluctuating conditions, the present difficulties would not have been so acute and the cost would have been more favourable. However, the present position of Britain, with regard to her depleted supplies of food and raw materials, is strong evidence that her Government is seeking peaceful solutions to the world's problems.

As can be expected the rate of spending to satisfy the needs of the defence programme will grow steadily, but considerable foresight will be necessary to enable the plan to proceed as rapidly as possible without disrupting the national economy. While every endeavour will be made to build up supplies of strategic materials, efforts will be made to regulate the use of these materials. It will be necessary to ensure that the scarce materials stocked will be released only for purposes for which there is no adequate substitute. This will apply particularly to the use of many alloying elements used in the production of ferrous and non-ferrous alloys. Fortunately, the fields of consumption were reviewed thoroughly during the war and various compositions and properties were scheduled for different uses. For instance, by means of fundamental rationalisation, two thousand or more different steel specifications contained in the record of the British Standards Institution were reduced to, roughly, ninety; thus it was possible to allocate raw materials, particularly high grade iron ore and ferrous alloys, on an equitable basis and to facilitate the placing of orders. It may be that further economies in the use of alloys may be found necessary, but the schedule developed at that time will form a useful guide to effect the maximum saving in alloy consumption. The importance of making the best use of available materials, in view of increasing world demand, was referred to by Professor Murphy in his Presidential Address to the Institute of Metals, in which he said "The use of a higher grade of metal than the application, or the method of manufacture, technically demands, or the unnecessary use of one metal in place of another more freely available, and likely to remain so, is metallurgically inefficient."

The idea of setting up a pool from which special machine tools, accessories and other equipment can be drawn, to assist in the fulfilment of Government contracts, is a good one; care will obviously be necessary to ensure that the best possible use is made of any machine obtained in this way.

The amount of money sought to cover the period to the end of March, considering the limited application, is very high and can be regarded as an indication of the staggering demands likely when the Budget is presented to Parliament, but building up stocks of essential materials likely to be in short supply will reduce the difficulties which would otherwise be encountered in putting the defence plans into operation.

Mond Nickel Fellowships

Applications invited for 1951

THE Mond Nickel Fellowships Committee invites applications for the award of Mond Nickel Fellowships for the year 1951. Awards will be made to selected applicants of British nationality, educated to University degree or similar standard, though not necessarily qualified in metallurgy, who wish to undergo a programme of training in industrial establishments; they will normally take the form of travelling Fellowships—awards for training at Universities may be made in special circumstances. There are no age limits though awards will seldom be given to persons over 35 years of age. Each Fellowship will occupy one full working year. The Committee hopes to award up to five Fellowships each year of an average value of £750 each.

Mond Nickel Fellowships will be awarded in furtherance of the following objects:—

(*a*) To allow selected persons to pursue such training as will make them better capable of applying the results of research to the problems and processes of the British metallurgical and metal-using industries.

(*b*) To increase the number of persons who, if they are subsequently employed in executive and administrative positions in the British metallurgical and metal-using industries, will be competent to appreciate the technological significance of research and its results.

(*c*) To assist persons with qualifications in metallurgy to obtain additional training helpful in enabling them ultimately to assume executive and administrative positions in British metallurgical and metal-using industries.

(*d*) To provide training facilities whereby persons qualified in Sciences other than Metallurgy may be attracted into the metallurgical field and may help to alleviate the shortage of qualified metallurgists available to industry.

Applicants will be required to state the programme of training in respect of which they are applying for an award, as well as particulars of their education, qualifications and previous career. Full particulars and form of application can be obtained from The Secretary, Mond Nickel Fellowships Committee, 4, Grosvenor Gardens, London, S.W.1. Completed application forms will be required to reach the Secretary of the Committee not later than June 1st, 1951.

The Universities and Industry

Study of Relations in America

A TEAM, under the auspices of the Anglo-American Council on Productivity, will shortly visit America to study the relationship between Universities and Industry in that country. The Team will include a Vice-Chancellor and three Professors of universities in the U.K., a secretary of a University Appointments Board, two Principals of Technical Colleges, four representatives of industrial management, a representative of the Ministry of Education and a representative of the T.U.C. Education Department. The Leader will be Dr. Percy Dunsheath, a Director of Henley's Telegraph Works Co., and also Chairman of Convocation of the University of London, and the Secretary will be Mr. A. L. Fleet, Assistant Secretary of the Association of Universities of the British Commonwealth.

Subjects for study will include the education of graduates and their employment in industry, the interchange of staff between Universities and Industry and the provision of research facilities. The enquiry will embrace not only scientists, engineers and other technologists, but men and women from all faculties at both graduate and post-graduate level.

The dollar costs of the visit are borne by E.C.A. whose New York office is preparing the itinerary in consultation with representatives of the Universities and of Industry in the U.S., and it is understood will include visits to a number of American Universities, industrial plants, and conferences with education and industrial organisations.

Awards

E.T.S. Gold Medal

THE Council of the Electrodepositors' Technical Society has awarded the E.T.S. Gold Medal for 1951 to Dr. S. Wernick. The Medal, which represents the highest award in the gift of the Society, will be presented at the Annual Conference to be held at Torquay in April. Dr. S. Wernick is the Honorary Secretary and Chairman of the Publications Committee of the Electrodepositors' Technical Society, of which he is also a Past President. He has carried out and directed considerable research in the electro-metallurgical field, which has led to numerous publications. He is the author of a recent book on "Electrolytic Polishing and Bright Plating of Metals." A graduate of London University, Dr. Wernick is a Fellow of the Royal Institute of Chemistry, and Fellow of the Institution of Metallurgists. He is consultant to a number of leading industrial concerns, which include The Austin Motor Company Limited, Wilmot-Breeden Limited, and W. & T. Avery Limited.

The Sir William J. Larke Medal

THE Institute of Welding has awarded the Sir William J. Larke medal for 1950 to MR. I. C. FITCH, Electrode Development Engineer in the Welding Department of Metropolitan-Vickers Electrical Co., Ltd., for his paper on "Arc Welding Electrodes—Their Uses and Abuses." This paper was first read by Mr. Fitch to the Manchester Branch of the Institute of Welding in February of last year, and has since been read at Plymouth and Preston. The medal is awarded annually by the Council of the Institute of Welding for the best paper of the year on welding, having regard to the originality of its contents and the style of its presentation. The medal was presented to Mr. Fitch at the Institute in London on February 28th, 1951.

The Joseph Whitworth Prize

MR. J. S. TURNBULL, Blade Engineer in charge of the Precision Casting Shop of the Metropolitan-Vickers Electrical Company at Trafford Park, has been awarded the Joseph Whitworth Prize for 1950 by the Institution of Mechanical Engineers for his paper on "The 'Lost Wax' Process of Precision Casting." The prize, to the value of £25, which is accompanied by a certificate bearing the seal of the Institution, is awarded annually for the best paper accepted by the Council on the subject of "Industrial Administration of Engineering Production."

The Copper Reverberatory Furnace

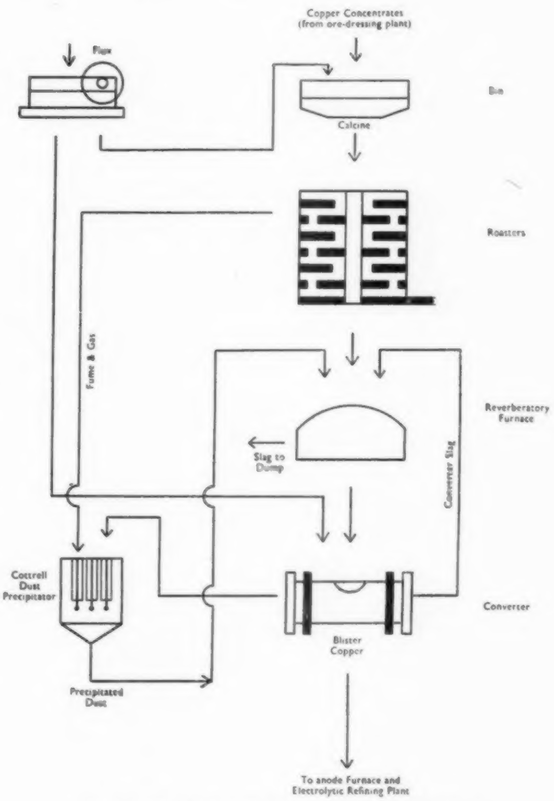
By W. H. Dennis

The increasing use of fine flotation concentrates in the production of copper has seen the reverberatory furnace displace the blast furnace for copper smelting. In this article, the author reviews some of the factors affecting the design, construction and operation of the modern high-production copper reverberatory furnace.

THE continually expanding field of copper usage, together with the exhaustion of the high grade copper deposits, has led to improved methods of ore dressing for the treatment of successively lower grade ores. During this period, the reverberatory furnace has always been prominent in smelting ore and concentrate, and the changing nature of the feed from coarse ore to fine flotation concentrate has, of necessity, exerted its influence upon furnace design.

The reverberatory furnace has not always had things all its own way, for as long as high grade coarse ore was forthcoming, competition came from the blast furnace with its low cost of maintenance and its small space and flexibility. The advent of flotation sounded the death knell of the blast furnace, however, as far as copper smelting was concerned, for it was not equal to the task of running down such fine material, which would either pack solid, interfering with furnace operation, or else would be carried out of the furnace by the ascending furnace gases.

To meet the growing demand for copper, the length of the reverberatory has continually increased from the small 14 ft. Welsh furnaces to as much as 150 ft. but now, owing to higher grade concentrates, and a better understanding of firing, 120 ft. is about the limit. Anything beyond this merely acts as extra settling capacity for the molten products. Size alone does not increase the tonnage: what is important is the rate of firing. When it is considered that only 25–30% of the heat input is effectively concerned in smelting, the rest passing out in the furnace gases or being lost in radiation, the question of providing efficient firing is of special significance.



Flow Sheet for Reverberatory Smelting.

Feed

The feed consists of calcine (the product of the roasters) or, in the more modern plants, unroasted concentrate direct from the flotation unit. The latter type of feed, when conditions permit, presents several advantages, and it is fairly safe to say that future smelters will incorporate it in their flowsheets as a matter of course. Amongst the more obvious features are :—

(1) Elimination of roasters and ancillary plant such as Cottrell dust precipitators,

(2) Reduction of dusting, both within and without the furnace, which in turn leads to two important benefits, (a) more pleasant working conditions for the furnace employees, and (b) less wear and tear on the interior furnace brickwork, resulting in longer furnace campaigns, and

(3) Magnetite nuisance in the reverberatory is greatly diminished for this ferric oxide is largely a product of roasting.

On the debit side there is, of course, the increased amount of fuel necessary to smelt the cold, wet (10% moisture) concentrate, as compared with the hot roaster product. On low grade material, wet smelting does not offer much advantage for, the roasters being better sulphur eliminators than the reverberatory, a low grade matte would result, which would necessitate a correspondingly larger converter capacity for the blowing of the matte to blister copper. Transportation of both the dusty, hot calcine and the wet, sticky concentrate to the reverberatory has, in the past, involved many headaches. In the case of the calcines, covered cars have been designed which haul direct from roaster to reverberatory with a minimum of both dust and heat loss and, by means of a specially designed feeder, charge the calcine direct into the furnace through panels in the side walls, there being none of the more usual drop holes or charge pipes in the roof.

Sometimes the plant has been so designed that the roasters are located directly over the reverberatory, the calcine being discharged to bins which are connected

with the reverberatory by charge pipes located along both sides of the furnace, adjacent to the side walls, in the smelting zone. The feed banks up, thus affording protection to the side walls against the corrosive action of the slag. Wet concentrate is brought to the furnace by means of vibrating conveyors which automatically discharge into the reverberatory feed pipes. In addition to calcine, the feed includes dust collected from the roaster and convertor by the Cottrell plant, flux (usually limestone) and molten slag from the convertors. This latter contains up to 5% copper, and is, therefore, too rich to be dumped. It is brought to the reverberatory and poured in through a spout in the smelting end of the furnace. Being rich in basic material (FeO) it acts as a flux (if this is needed).

Refractories and Construction

The development in the size of the reverberatory necessitated by the increased demand for copper has led to exacting demands on refractories. The increase in hearth area has involved heavy stresses and strains within the refractory lining, accentuated by the throughput of large tonnages and the high temperatures necessary for economic operation. In addition, the lining is subjected to abrasion, mechanical erosion, and corrosion by the chemical action of slags, fluxes and gases such as chlorine, sulphur dioxide and superheated steam.

To meet all these demands successfully would necessitate a refractory possessing good load-bearing capacity, maximum resistance to spalling and slag corrosion, rigidity under high temperature, etc. One could not expect to find a brick capable of withstanding all these varying conditions and a compromise has therefore to be made on the refractory (or refractories) which possesses two or three of the essential qualities for the purpose in view.

Silica brick has been, and still is, widely used in all parts of the furnace, and in this respect has rendered pioneer service in the expansion which has taken place in smelting. It possesses good load-bearing capacity at high-temperature, constancy of volume, and a high temperature of incipient fusion. Its resistance to changes of temperature below a dull red heat is not very great, however, nor is its resistance to slagging all it might be, owing largely to its porosity and acid character. In the early reverberatories, the hearth was constructed over an open space through which air circulated, with the idea of keeping this portion of the furnace cool! The area was arched over and supported the hearth which was in the shape of a shallow pool enclosed by walls of fire-brick supporting the roof. Later it was recognised that this space led to severe heat losses, for the heat was being dissipated where it was most needed and this error was accordingly rectified by giving the furnace a solid bottom of concrete or slag.

The present day reverberatory (Fig. 1), although differing in detail according to the ideas of the various smelters, follows the same general outline. The hearth is of sintered sand, usually 2 ft. thick, resting on a concrete bottom up to 8 ft. in thickness to ensure adequate support for hearth and charge. Arising vertically along the furnace sides are steel I-beams usually spaced on 5 ft. centres. Technically known as buckstays, they are connected over the top of the furnace by tie-rods serving to hold the furnace together and resisting the thrust of the hearth and charge. The side walls are of silica brick, with two or more courses of magnesite brick extending from the hearth to above the slag line. Walls are thick and sometimes stepped, the better to withstand lateral pressure, being 4–5 ft. thick below the slag line and tapering off to about 1 ft. at the top. Occasionally let into the walls in the smelting zone are water coils for the purpose of cooling the surrounding brickwork and thus preventing a possible collapse of the buckstays.

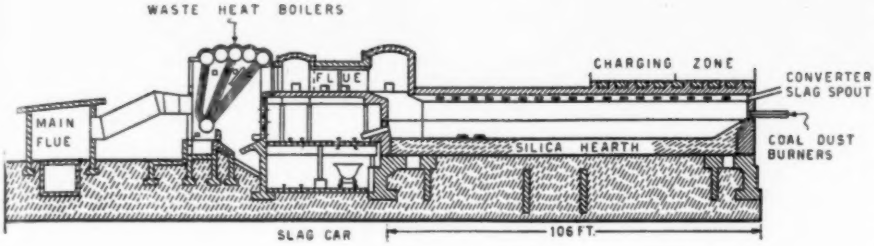
As the bricks expand in all three directions when heated, provision has to be made to accommodate this increase in bulk. Horizontal expansion is provided for by means of vertical expansion joints. In silica brick reverberatories, vertical expansion joints consist of open spaces or slots extending from top to bottom of the walls, 10–16 ft. apart. Provision may be made for lengthwise expansion of the roof arch by insertion of wooden strips, or by leaving open joints across the roof at intervals. Transverse thermal expansion is automatically compensated for by the rising of the arch, slight compression of the hot ends of the bricks being taken care of by adjustment of the tie rods.

In no part of the refractory structure are proper design and construction more important than in the arch. Among the factors which determine its stability are the materials of which it is built, the rise, thickness, length of span, furnace temperature and the stability of buckstays and skewbacks. Movement of the latter was one of the most common causes of arch failure resulting from defective foundations or overheating of the metal plating. Another factor leading to failure of the roof is chemical action. Dust created in charging the furnace, fume and gas from operation, and especially coal ash from the burners, are all extremely corrosive and react readily with the hot end of the brick.

A roof where silica brick is employed is always of the sprung arch type, a single layer of brick up to 20 in. in thickness being used. The span rests against the skewbacks running along both sides of the furnace and bolted to the buckstays. These take up the thrust of the arch. As the roof is self-supporting over the whole span, its width is necessarily limited by the weight and crushing strength of the bricks at the temperature of operation. This width for silica brick is about 25 ft. The roof is generally horizontal throughout its full length. (In the early days the roof sloped steeply towards the front of the furnace in order to bring the hot gases into close contact with the bath. Modern methods, however, necessitate an adequate draught area in the front for the escape of products of combustion).

A development in roof construction, which has met with much success, is a mechanically suspended type of arch employing magnesite brick. Magnesite, being more than 50% heavier, is denser than silica and possesses a lower crushing strength and it has not yet been possible to maintain a sprung arch of magnesite brick under working conditions. The bricks are, therefore, suspended from horizontal supporting rods above the furnace.

The Canadians have been in the forefront in adopting this type of roof construction, the Hudson Bay Mining and Refining Co., Manitoba, having been one of the pioneers. The average life of a silica arch in their reverberatory was 60–75 days, failure occurring mainly around the charging holes and skewback bricks, chiefly through fluxing action. In consultation with their refractory manufacturers, unburned magnesite brick was installed on the shoulders on each side of the arch,



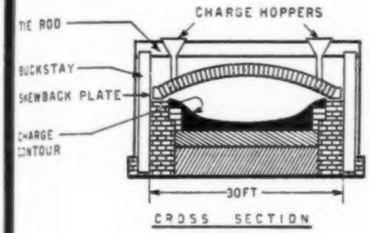


Fig. 1.—Copper reverberatory furnace with waste-heat boilers.

extending 16 courses out from the skewbacks for a length of 20 ft. in the smelting zone, silica brick being retained in the centre. On firing the furnace, failure occurred in the silica brick adjacent to the magnesite shoulders and it was decided to extend the magnesite an additional four courses. This increased the life to 95 days but failure again occurred in the silica brick. The next step was to construct the entire arch of magnesite. The brick manufacturers, however, advised against a sprung arch, owing to the low crushing strength of magnesite at high temperatures, the only alternative being a suspension type roof. A section 27 ft. in length was put into operation and lasted 370 days—nearly four times as long as the best life from a sprung arch. During this period a hole burned through, but improvised patches enabled the furnace to carry on without closing down.

Later, the arch was extended another 23 ft. making 50 ft. in all. A feature in the construction is the insertion of steel plates $\frac{3}{32}$ in. thick between the rows of brick so that there is a plate on each of four sides of each brick. These plates, under the influence of heat, weld themselves to the brick at the hot face, which not only seals the joints but prevents any possible spalls from falling out. Owing to the fact that magnesite brick has a higher heat conductivity than silica brick, it was expected that more pulverised fuel would be necessary to smelt the same tonnage. However, this did not turn out to be the case and actually the fuel ratio was better. With a silica brick arch, 7·7 tons of charge was smelted per ton of coal, whereas with magnesite 9·3 tons was obtained. The latter figure is, of course, not directly attributable to the use of magnesite but is explained by the fact that fewer shutdowns enabled fuel to be saved in the starting-up periods.

The increased life of the furnace due to the use of magnesite made it necessary to increase the life of the side walls, in the smelting zone, and the front wall, and these were also lined with magnesite brick. The increasing basicity of the charge as a result of higher grade flotation concentrates is thus causing an increasing use of basic refractories in those parts where corrosion is most severe, e.g. at or below the slag line, the front and bridge walls and the arch.

Another area of corrosion is to be found around the charging holes and converter spout. This is caused by air, for wherever air can gain admittance and meet the charge in the presence of silica brick the latter is corroded.

The refractory situation in modern practice is aggravated by the need for good fuel ratios which are dependent upon putting through large tonnages, thereby heightening the wear and tear on the brickwork. Dusting especially gives rise to extensive corrosion in the roof arch.

Lessening this nuisance would give a greater capacity to the furnace by a lengthening of the operational campaign. Hence the introduction of the Gar gun, wet smelting, etc. The former was developed at the Garfield plant of the American Smelting and Refining Corporation and consists of a telescopic water-cooled pipe which is connected up to the calcine car and introduces the hot calcine directly into the furnace under the gas stream of the combustion zone, thus ensuring quiet distribution. The gun is telescoped through a port in the side of the furnace and is withdrawn after use. Five guns are used per furnace. At the Garfield plant the campaign before the use of the feeder was 80–100 days, smelting an average of 800 tons per day. By hot patching this could be extended another 20 days. With the aid of the feeder the campaign was extended to 200 days, the rate of smelting being increased to 1,000 tons per day.

Dusting of the charge when finely divided calcine is dumped into the furnace is also avoided when wet smelting (i.e. feeding in of undried flotation concentrates) can be introduced, and in consequence repairs and replacement of refractories are much reduced. For instance, at the Miama smelter of the International Smelter Corp., during the period of calcine smelting, the furnace campaign rarely exceeded nine months, at the end of which time it was necessary to shut down for general repairs entailing side wall, and roof arch replacements and renewal of the header flue. In addition, during the campaign, at least two arch replacements were necessary in the smelting zone, involving 20–40 ft. of arch and upper side walls. It was generally considered that for calcine a 90 days' run for that section of the arch in the smelting zone was a good performance. Since the adoption of direct charging of raw concentrates, the campaign now extends over two years. During this time some hot patching and arch replacements in the smelting zone have been carried out, but it is noticeable that the length of service of smelting zone arch has been extended from three months to from six to nine months. No repairs during the two years were necessitated by the side walls.

Mention has been made of hot patching. This is a method of prolonging the furnace campaign by spraying a water suspension of refractory material on to the corroded surface while the furnace is still under fire. Refractory patching material is made of crushed quartz, sand or bentonite and a slurry of clay which has been treated with steam for several hours to ensure thorough disintegration. The mixture is blown on by a spray gun, using compressed air, and is applied in successive layers allowing sufficient time between the applications to

permit the heat of the furnace to dry out the refractory.

A further method of prolonging the life of the roof is the method of ribbed arch construction. Here the roof is constructed with ribs spaced every few feet. When the arch becomes thin through corrosion, silica brick is fitted in between the ribs and over the corroded area, thus restoring the original thickness and permitting operations to continue.

Insulation also provided a lengthening not only of the roof life, but also of the whole furnace campaign. The quantity of heat passing out through the furnace is appreciable, as anyone who has worked round a reverberatory can testify. As the aim is always to improve the fuel ratio, this heat loss is of considerable significance and insulation has come to be widely practised. The heat saving is equivalent to that which would be obtained with a refractory wall many times as thick. The insulation provides an additional obstruction to the infiltration of cold air, thus further improving furnace efficiency. The Cananea smelter in Mexico completely insulate their reverberatories with an 8 in. coating of a vermiculite preparation. This permits a possible draught in the furnaces of 0·06 to 0·10 in., a suction that would draw too much cold air into an uninsulated furnace. In addition, the insulation lengthens the arch life by cutting off leakage of air both inwards and outwards. Arch life is at least two years and some arches last four years.

Smelting

Chalcopyrite is one of the most prevalent ores of copper occurring in practically every copper ore mined, and for the purposes of illustration it is convenient to consider the following reaction :

$$\underset{\text{(Chalcopyrite).}}{Cu_2S\,Fe_2S_3} + \text{heat} = \underset{\text{(Copper matte).}}{[Cu_2S + 2\,FeS]} + S \uparrow$$

On heating it loses some sulphur (which forms sulphur dioxide) and splits up into a mixture of iron sulphide and cuprous sulphide which comprise copper matte.

Not all iron enters the matte, for preliminary roasting has oxidised part of the iron pyrites radicle, and this combines with silica in the gangue material to form ferrous silicate which constitutes slag. This, in the main, is what takes place, but it is not a true picture, for in addition to sulphides there are present in the feed, oxides and sulphates which react in a number of different ways. However, it is a simple and convenient method of showing the main course of the reaction.

The amount of sulphur in the feed to the reverberatory determines the matte grade, i.e. the copper content. Roasting reduces the amount in combination with iron (but not copper for Cu_2S is stable) and when smelted there is less iron sulphide to enter the matte, the net result being that a concentration of copper takes place. In the case of raw concentrates which are introduced direct into the reverberatory, elimination of sulphur does not take place to such an extent as in the roasters and therefore a lower grade matte results.

The more usual grade of matte ranges from 35–45% copper, although considerable variation takes place outside these limits. The highest grade of matte, i.e. the one containing the greatest concentration of copper is not necessarily the most economic to aim at, for this, involving as it does a high degree of roasting, gives rise to attendant high costs and dust. A moderate cost only is involved in roasting a concentrate containing say 35% sulphur down to 15%, for concentrates are self-roasting down to this limit and would not require any fuel; other factors also come into play such as high copper losses in the reverberatory slag and production of magnetite. The latter is a nuisance in reverberatory operation for, depending on the specific gravity of the matte, it either blankets it, hindering the efficient separation of matte and slag, or else sinks through on to the furnace hearth, forming accretions which eventually necessitate the closing down of the furnace for hearth renewal. Magnetite, as such, cannot enter into combination with silica and be eliminated in the slag, and the only way to deal with it is to have present sufficient FeS which reduces it ($FeS + 3Fe_3O_4 = 10\ FeO + SO_2$), the FeO then combining with silica in the normal way. If the concentrate has been roasted to a low sulphur content in order to produce high grade matte, there will be insufficient FeS to effect reduction of magnetite, the remedy then being to add raw concentrate to the reverberatory charge.

As a result of the smelting action, matte and slag are formed and flow from the smelting end of the furnace to the front or settling zone where they separate into two layers. The bottom layer of matte is tapped intermittently from the side of the furnace into ladles and conveyed in a molten condition to the converter plant. Slag flows continuously from the front end and is usually led to the dump. Its composition varies from 30–35% SiO_2, 40–45% FeO, 5–8% Al_2O_3, 2% CaO and 0·3–0·5% Cu. Sometimes slag is crushed and used as fertiliser. It has also been employed as street paving blocks by laundering in a molten condition to square moulds and allowing to set.

Fuel

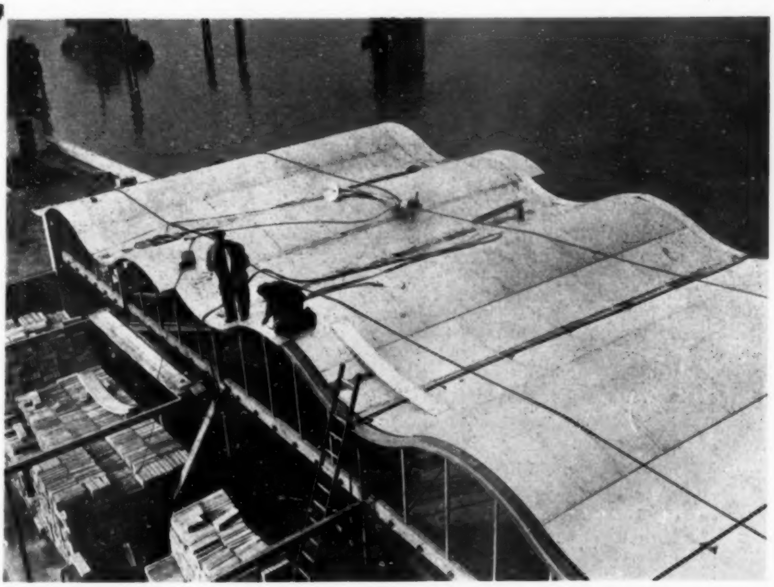
Types of fuel used in copper smelting include pulverised coal, fuel oil and, where available, natural gas, the first-named being most widely used. When first introduced trouble was experienced from many directions. Due to unburnt particles of coal falling on the charge, preventing any effective amount of heat from penetrating, smelting action was hindered and, in many cases, the bath froze up. Finer grinding was the answer to this, for it was found that the trouble was caused by insufficient pulverisation and that when ground to 85% –200 mesh, combustion of the fuel was more complete and conditions inside the furnace improved. In spite, however, of the more rapid combustion, tonnage was still inclined to lag behind, and it was some time before it was realised that the sloping roof and narrow uptake and flue were responsible. This type of construction had served when the furnace was coal fired but could not handle the large volume of gases resulting from the much more rapid combustion of the pulverised fuel. By abolishing the slope of the roof and enlarging the uptake, conditions favourable to a large increase in the tonnage were instituted. It is now recognised that the more fuel units that can be burned per ton of charge, the better the tonnage and also the fuel ratio, and accordingly ample area must be provided both at the firing end, for combustion, and the flue end, for removal of gases.

Burners numbering 4–7 are set horizontally in the rear end of the furnace wall. Their position is important for they should be well away from the roof so that there is sufficient space for combustion and also, incidentally, to avoid any danger of the flame impinging on the roof and causing erosion thereof. At the same time they

should be high enough above the charge in order that the calcines will not be sucked up, causing dust storms within the furnace. Primary air is conveniently used to blow the pulverised fuel to the burner, secondary air being admitted via a port and regulated to provide a short hot flame.

Of the total heat supplied to the furnace, some 50–60% passes out in the waste gases and as these have a temperature of up to 1,300° C. the utilisation of this waste heat is standard practice, being effected by the installation of waste heat boilers. These are generally of the Stirling type with vertical water tubes. Much fume and dust from the gas settles on the tubes, impeding efficiency, and this is, to some extent, provided for by automatic steam blowers attached to the boiler which keep down much of the deposit. Eventually, however, the boilers have to be shut down to clear off slag and other accretions. For this purpose by-passes are built so that the boilers can be put out of action without interrupting the operation of the furnace. Gases after leaving the boilers still contain appreciable amounts of heat, and by the use of recuperators attempts have been made to utilise this heat by preheating the secondary combustion air. Success has been difficult of attainment, owing largely to dust in the gas accumulating in the 'passes' of the recuperator which consequently quickly becomes choked, thus putting it out of action. However, some smelters manage to pre-heat their air to 300° C.

Sandwich Roofing for Festival Restaurant



THE material used in the roofing of the Thameside Restaurant on the Festival of Britain site is an aluminium sandwich insulated panelling developed and patented by Messrs. Alphamin, Ltd. The cork sandwich panel was not designed specifically for this particular application but had been in the course of development for a short time when the architects for the Restaurant, Fry, Drew and Partners, saw it and specified its use on the Restaurant roof. It is believed that one of its main uses will eventually be for curtain walling of steel-framed industrial buildings. Curtain walling has been widely used in the United States but so far in this country little work appears to have been done.

The Restaurant roof, which is now almost complete, passes beneath Waterloo Bridge and is already a most impressive sight. In elevation, the roof follows a wave-shape as may be seen from the Embankment. The roof, which covers one-fifth of an acre, is 27 ft. between front and back columns, the front columns being at 14 ft. 2 in. centres, and those at the back varying due to curvature in plan. The radius of the sheets is 6 ft. 9 in., and the valleys fall 3 in. from front to back. In the construction of the roof 6½ tons of aluminium sheet and extrusions were used, including 1·13 miles of 2¼ in. × 18g. BA.60 strip and some 250,000 ⅛ in. dia. pop rivets. A prototype bay of the roof was loaded with 5 tons of plate, i.e. it successfully withstood an applied load of 30 lb./sq. ft.

The standard slabs weigh 2·25 lb./sq. ft. and consist of 2 in. of pure baked cork slab glued between two sheets of 20g. BA.60 sheet. This is an aluminium alloy containing manganese which has good resistance to atmospheric attack and was selected from the aluminium alloys available for that fact and because of its strength and comparatively low cost. The slabs, which may be flat or curved to a radius of not less than 6 ft., are available at 8 ft. × 4 ft. and 8 ft. × 3 ft. 4 in., or any size to order up to 10 ft. × 4 ft. Joints between slabs may be made by cover strips riveted on either side of the joint with blind rivets, by H-shaped extrusions riveted in the joint, or by an interlocking joint.

The main advantages claimed for the material are (*a*) its light weight, permitting a reduction of foundation and framework weights and costs ; (*b*) it gives a permanent exterior and interior finish without plaster, etc. ; (*c*) it gives more floor space owing to its thinness ; (*d*) its good insulating properties (K = 0·14 B.Th.U./sq. ft./°F.) make it equivalent to more than 40 in. of brickwork ; (*e*) its light weight makes very easy erection ; (*f*) in a building designed in terms of the qualities of this material, considerable economies can be effected.

APPLIED High Frequency, Ltd., have recently concluded agency agreements with the following :—

For Scotland : Messrs. John S. Young & Co., Ltd., 257–261, Eglington Street, Glasgow, C.5.

For S.W. England (including S. Wales) : Messrs. Hocking & Orchard, Ltd., 90, Victoria St., Bristol, 1.

Production and Metallurgical Characteristics of Mining Hollow Drill Steel in Australia*

By Daniel Clark, F.I.M.

The change from solid to hollow drill steel for mining took place in the second decade of the present century. A number of factors contributed to this step and in this article the author deals with the historical aspects of the change, including the developments in hollow drill steel manufacture, and concluding with an account of present day practice.

Historical

SINCE the introduction of improved high-air-pressure drilling machines in the early part of the century, efforts have been made to enhance the quality of the rock drill bit, in order to take advantage of the greater increase of power output per unit weight of the machines.[1] This resulted in the change from solid to hollow steel in the second decade of the present century.[2]

As the greatest sufferers from the dread disease of silicosis,[3] it seemed appropriate that the South African gold mines organisations should be the first to employ hollow drill steel, since which time solid drills have become practically obsolete for mining purposes.

The use of water with hollow steel drills not only serves to keep the cutting end cool, but assists in allaying dust generated during drilling. It is of interest to note, however, that water fed through hollow steel or sprayed into the air is only partially effective in removing fine dust particles of a few microns in diameter, the size believed to be most potent in inducing silicosis.[4]

In so far as the composition of "straight" carbon steel drills is concerned, we have the findings of a commission appointed by the Johannesburg mines to carry out a very exhaustive series of drilling tests. The drills were manufactured from steel made by standard processes, embracing Bessemer, crucible, open-hearth, and, to a limited extent, the electric furnace. It should be remembered that the commissioners' report was issued in 1913, when hollow drill steel had not yet been introduced. Only solid steel drills were then in use.

This report stated that, for the larger rock drills, from $1\frac{1}{2}$ in. upwards, the best results were obtained with a carbon content not exceeding 0·66%, while for smaller drills, down to $\frac{7}{8}$ in., optimum results were obtained from steel not exceeding 0·72% in carbon.

In America, under average conditions, the following analysis was regarded as suitable for straight carbon drill steel: carbon 0·85–0·90%; manganese 0·30–0·40%; and phosphorus and sulphur each 0·03% maximum. It is well understood in mining circles that a high carbon steel demands greater care by the blacksmith, and whilst less readily weldable than a low carbon steel, gives much better performance. A. E. Perkins[5] defines a good rock drill as :—"The best steel for a fixed set of conditions is the steel that will withstand the duty imposed upon it without undue breakage and will withstand the abrasive action of the rock with the least amount of wear."

British mining drill steel conforms closely to the following specifications :—carbon 0·62–0·68% for the softer rock, and 0·72–0·78% for the harder rock, with silicon 0·2%, sulphur and phosphorus combined 0·04% max., and manganese 0·40%. In the case of particularly hard rock, it has been found advisable to increase the carbon content to a range of 0·87–0·93%, but as has already been mentioned greater care in forging and heat treatment becomes necessary.

Until 1921 practically all rock drills used were made of carbon steel,[6] but it was found that to obtain the maximum benefit from the heavy rapid blows of the improved pneumatic hammer, without increasing the weight or section of the drill steel bar, it was necessary to add certain alloying elements to the steel. Thus[7] the addition of 0·30% molybdenum was made, which gave greater latitude to the heat treater.

A drill steel stated to have given from two to three times the life of carbon steel in endurance tests and actual service had the following composition :—carbon 0·78–0·85%; manganese 0·25–0·35%; phosphorus under 0·020%; sulphur under 0·025%; silicon 0·12–0·16%; and vanadium 0·20%[7]. This low alloy steel has a wider hardening and forging range than ordinary carbon steels. It will harden satisfactorily at any temperature between 760° C. and 840° C., while retaining its quality of hardness and toughness throughout.

However, the fact that alloy steels generally demand more care in forging than is necessary for carbon steels, together with more accurate temperature control during heat treatment, has seriously interfered with their wider use in the mining industry.

It is of interest to note the results of tests carried out on a total of over 190,000 tools sharpened, which were published in the Canadian Mining Journal, Jan. 15, 1917 and referred to by Foley.[8] This indicated that the cause of hollow drill steel breakages was due chiefly to faulty manufacture (slag or oxide inclusions in the bore of the hollow steel) or improper heat treatment, rather than fatigue. This finding conflicts with the statement of Hatfield in his article "Drill Steels for Mining Purposes"[9] in which it is stated : "Most failures are due to fatigue or wear."

It is well known that corrosion fatigue is a fertile

* We are indebted to the Australian Institute of Mining and Metallurgy for permission to present this paper, which was read at the Annual Conference at Newcastle, N.S.W., in May 1947, but has not hitherto been published.

1 *Transactions of the American Institute of Mining and Metallurgical Engineers*, (*Trans. A.I.M.M.E.*), 1921, **66**, 779.
2 *Transactions of the Institute of Mining and Metallurgy (London)* (*Trans. I.M.M.*), 1933, **42**, 543.
3 *Trans. I.M.M.*, 1933, **42**, 541.
4 *Chemical Engineering and Mining Review*, Nov. 6th, 1933.
5 *Trans. A.I.M.M.E.*, 1921, **66**, 812.
6 *Trans. A.I.M.M.E.*, 1921, **66**, 779.
7 *Trans. I.M.M.*, 1933, **42**, 506–7, 519.
8 *Trans. A.I.M.M.E.*, 1921, **66**, 789
9 *Trans. I.M.M.*, 1933, **42**, 505.

source of drill failure.[10] The water in many or most metalliferous mines is likely to be acidic, and therefore liable to set up small cracks in the wall of the aperture in the centre of a hollow drill. When subjected to alternating impact in service, these cracks serve to concentrate the stresses, with the result that fracture is likely to occur. By building the drill around a rust-resisting tube, a well-shaped hole is obtained with smooth rustless walls and the incidence of corrosion fatigue is thereby reduced. Assuming proper precautions are taken to prevent the occurrence of corrosion fatigue the loss from premature failures should show a substantial decrease. The question, however, of employing a stainless-lined drill rod is one that can only be determined by consideration of economics dictated by local conditions.

Types of Drill Bits

Many types of bit have been used at various times, and the following are some of the better known :—The "single-chisel" bit, the "double-chisel" bit, the "cross-bit," the "rose-bit," the Z-bit, the Y-bit, and the "twisted auger" bit. Of these, the "double-taper cross-bit" and the modification of the "single-bit," known as the Carr bit, are of general application and give excellent service. With reference to these two latter drills, Hatfield[11] states "The cutting angle of the cross-bit is normally about 90°, but may be increased to as much as 105° in hard ground (with consequent loss of cutting speed) or decreased in easier ground. A taper of 5° is allowed to give clearance, and the hole may on occasion, be bell-mouthed. The thickness of the wings is important, and on $1\frac{1}{4}$ in. steel in hard ground should be about $\frac{5}{8}$ in. If too thin, chipping of the corners will inevitably result. If, on the other hand, they are too heavy, insufficient clearing for the cuttings is allowed.

"The Carr bit has a 120° cutting angle and a 5° taper from the corners; it is a fast-cutting bit with good clearance. The tool operates by means of a series of percussive blows delivered with rotation : the angle of the tool, as has been shown, being comparatively blunt for hard ground. The action is in no sense a 'cutting' action, but essentially a 'crushing' by 'shearing.'"

Discussing the comparative superiority of different sections, E. A. Perkins,[12] states that the cruciform section is inherently a weak section, and shows the greatest number of breakages in service. It contains less steel per foot than any other standard section of the same size and when rolled the wings tend to cool off, setting up cooling stresses.

Evolution of Cored Holes[13]

The Sand Core.—When hollow drill steel was first introduced this was the type of core employed. The hole in the billet was tightly packed with silica sand and at each end a plug was inserted and riveted over. After rolling, the two ends embracing the riveted areas were broken off and the sand cleaned out by means of a high-pressure water jet.

The wall of the hole left in the finished drill rod by this method was always more or less roughened, and many of the fatigue failures encountered in service were traceable to this condition.

The Copper Core Process.—This process for making hollow steel drills was initiated and developed in Britain. A hole is made down the centre of the billet, and a rod of copper inserted therein. The billet is then heated, rolled, and allowed to cool, after which the rod is removed, leaving a hole through the entire length of the bar. According to Hatfield[14], molten copper was first used to fill the hole in the billet.

Although this was an improvement on the sand core process it has some serious disadvantages. Copper melts at the comparatively low temperature of 1,083° C., and the copper rod is therefore in a soft condition during the rolling process, with the result that the hole is liable to be irregular in shape. Moreover, owing to the limited resistance offered by the soft copper bar during rolling, the grain structure may not always be as fine as it should be in a good drill steel. On the other hand due to copper impregnation, it is conceivable that copper cored drill steel would give enhanced resistance to the corrosive influences of contaminated mine water.

The Austenitic Steel Core Process.—As with the copper core the austenitic core was also first introduced and patented in Britain. Compared with the drill steel itself, this steel has a greater coefficient of expansion on heating and greater contraction on cooling. An additional feature is its extraordinary capacity to stretch evenly along its entire length before fracture takes place, a factor greatly facilitating its removal from the drill rod when pulled from both ends.

An austenitic core steel offers considerable resistance at rolling temperature, which not only assists in leaving a smooth hole surface but contributes greatly in ensuring a good grain structure in the drill rod.

Casting Around a Tube.—To overcome the disadvantage of core removal, a method was developed of casting the drill steel around a mild steel tube.[15] This process found favour for a time in certain parts of the British Dominions, but as far as is known is not now in use. The method consisted of placing a mild steel tube in the centre of the ingot mould, and flowing the drill steel between the tube and the mould. The tube may be filled with sand to prevent distortion of the hole during rolling.

A weakness in this process lies in the fact that on cooling the molten ingot, solidification begins where the cold tube comes in contact with the liquid steel, and also where the liquid steel is in contact with the cold mould. The impurities are therefore expelled into a midway position between the hole and the outside of the bar, where final freezing takes place. From the standpoint of the drill steel user, this is undesirable because the body and cutting edges of the finished drill embrace the segregated area, thus inviting breakages and unreliability in service.

Another weakness was that the ingots produced were small and, therefore, the amount of work performed on them during rolling was generally insufficient to break up properly the coarse cast structure.

An ingot made in the conventional manner cools from the outside inwards, so that the undesirable impurities are aligned down the central area. When the resultant billet is drilled along the axis, most harmful impurities and inclusions are removed, thus giving strength to the drill and rendering it less likely to fail in service.

Stainless-Lined Holes.—Corrosion fatigue has already been mentioned as a fruitful source of mining drill steel failures where the mine water is of an impure nature. Where the hole walls are rough, as in the case of hollow

10 *Trans. I.M.M.*, 1933, **42**, 502, 505 and 543.
11 *Trans. I.M.M.*, 1933, **42**, 493–5.
12 *Trans. A.I.M.M.E.*, 1921, **64**, 8.
13 *Metals and Alloys*, Feb. 1943, 320 *et seq.*, *Trans. I.M.M.*, 1933, **42**, 507 *et seq.*
14 *Trans. I.M.M.*, 1933, **42**, 507 *et seq.*
15 *Trans. I.M.M.*, 1933, **42**, 508, and *Metals and Alloys*, Feb. 1943, 324.

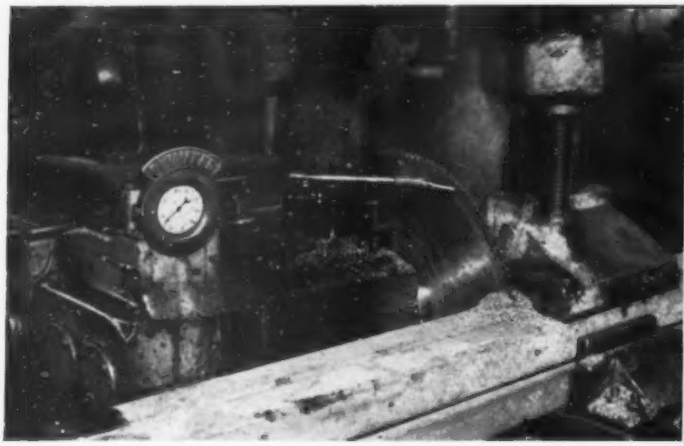


Fig. 1.—Cold-sawing billets to length.

steel drills prepared by rolling on a sand core, corrosion is liable to commence at any imperfection in the lining of the hole. Once corrosion pits form, they become nuclei which rapidly enlarge due to acceleration of the rate of corrosion, and corrosion fatigue effects follow.

To overcome the troubles induced by such crorosion, without sacrificing the advantages associated with the central idea, the mild steel tube was replaced by one of stainless steel[16]. At first an austenitic 18/8 stainless steel was used, but due to the fact that the coefficient of expansion between the drill steel and the tube differed considerably, the weld between the two was found to be imperfect. Again, the carbon in the drill steel exhibited a tendency to diffuse into the stainless steel lining, thus reducing its corrosion-resisting properties. The 18/8 stainless steel was therefore replaced by a ferritic stainless iron containing about 0·10% carbon and 13% chromium, which is claimed to have given satisfactory results in service. This method, however, suffers from the same disability as the mild steel tube process already described in that, as freezing proceeds from both inside and outside, the impurities which segregate out on final freezing, and cannot be removed, may detrimentally influence drill life.

16 *Trans. I.M.M.*, 1933, **42**, 508, and *Metals and Alloys*, Feb. 1943, 325.

Fig. 2.—Billet drilling operation.

Manufacture

In the initial stages, i.e., steel making, ingot pouring and preliminary rolling operations, the manufacture of hollow drill steel does not depart significantly from normal high-grade steel practice. For this reason the processes described begin at the billet stage and are confined to those more or less peculiar to hollow drill steel production.

Preparation of Billets for Rolling

Commencing with 3½ in. square billets, previously conditioned and inspected to ensure freedom from harmful surface defects, a test piece is cut to provide information as regards the hardening characteristics of the particular heat represented. This test piece is

Fig. 3.—Core tack-welded.

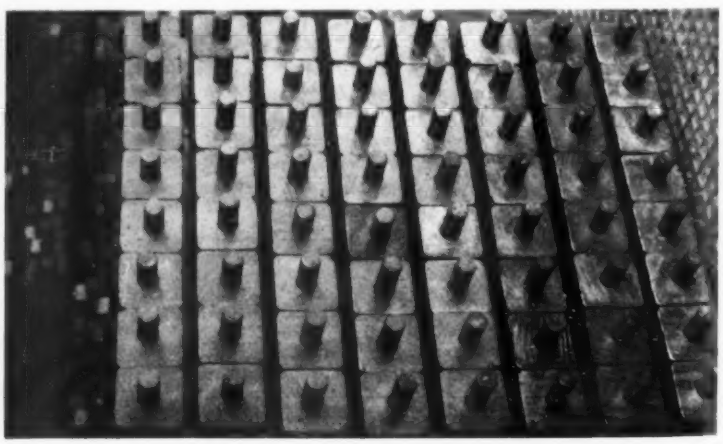


Fig. 4.—Cored billets ready for tack welding.

Fig. 5.—Hot-rolling in the 12-in. mill.

maximum temperatures attained. For this reason the billets are heated in a continuous furnace, the total heating and soaking time being about 3 hrs., of which 2–2½ hrs are occupied in raising the temperature to 1,000°–1,050° C., the remaining ½–1 hr. being a soaking period to ensure uniform temperature throughout.

Depending upon the section being rolled, the temperature at the commencement of rolling varies between 1,000° C. and 1,050° C., and is designed to enable the normal rolling sequence to be completed at a temperature of about 850°–900° C. If the temperature at completion of rolling be too hot or too cold, the one condition is liable to produce a coarse-grained structure and the other invoke a high internal stress, either of which tends to increase the risk of breakage in service in the body of the drill itself.

prepared by forging to 1¼ in. square, turning to 1 in. diameter, and drilling an axial hole to simulate the shank end of a drill. A standardised heat treatment is then carried out prior to a comprehensive Rockwell hardness check being made.

On completion of this test, a clearance is issued to the mill, and the billets are then cold sawn to provide a length of 3 ft., each sawn billet weighing approximately 121 lb. Fig. 1 shows a cold saw cutting off the billets to length. It will be seen that four billets are cut at one setting.

To obtain the requisite hole in the finished bar, it is necessary to drill the billets at this stage to permit the insertion of the special core which is subsequently removed after final rolling. This drilling operation is carried out in specially developed Baker drills, the aim being to provide a smooth and truly concentric bore 1 in. in diameter. Fig. 2 shows the machines on which the operation is performed.

Referring now to the core, it is necessary to employ a material which is extremely tough and ductile since any brittleness or lack of ductility will hinder its extraction, and may even entirely prevent removal. In addition to this requirement it is, of course, essential to avoid the use of a material which would either partially or completely weld to the bore of the steel during rolling or would produce an uneven or pitted bore surface.

These conditions are fulfilled by a special austenitic grade of steel which has been developed solely for this purpose. This core steel is produced in electric furnaces under carefully controlled conditions and is rolled to $\frac{31}{32}$ in. diameter so as to fit the drilled hole in the billet. To secure these cores in place during heating for rolling, etc., they are tack welded as shown in Fig. 3. It will also be noted that the core is left approximately 2 in. longer at each end than the actual billet. This prevents the ends " over-rolling " the core and takes care of its movement should the welds fracture during the early passes. It also facilitates subsequent extraction. Fig. 4 shows a stack of cored billets just prior to the tack welding operation.

Heating for Rolling

In view of the high carbon content of the drill steel, it is most sensitive both to actual heating rate and to

Rolling

Depending upon the size and section of the finished steel, the heated billet is passed between 17 and 25 times through the mill, each pass being designed to reduce the cross section without irretrievably deforming the central hole or producing defects on the bore surface. Fig. 5 shows the rolling operation in the 12 in. mill and indicates how the heated billet is passed back and forth

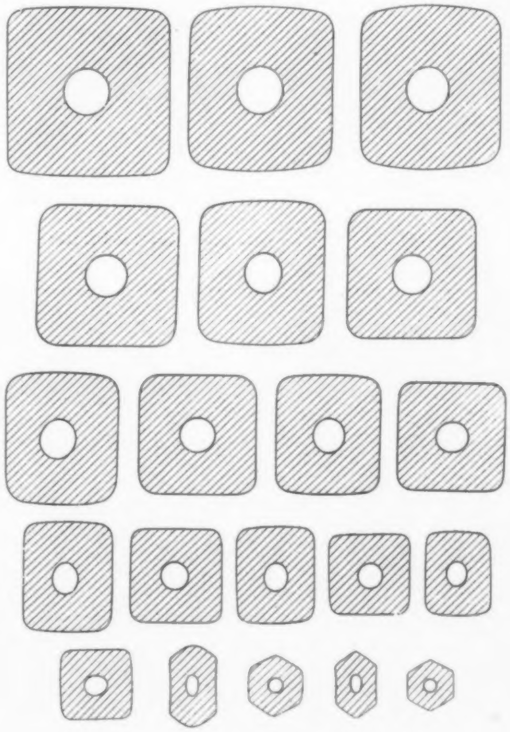


Fig. 6.—Stages in the rolling of 1 in. hexagon bars.

Fig. 7.—The cooling bank.

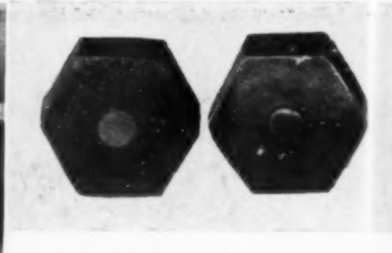


Fig. 10.—Showing reduction of core diameter in extracting.

Fig. 8.—Snicking bars with abrasive wheel.

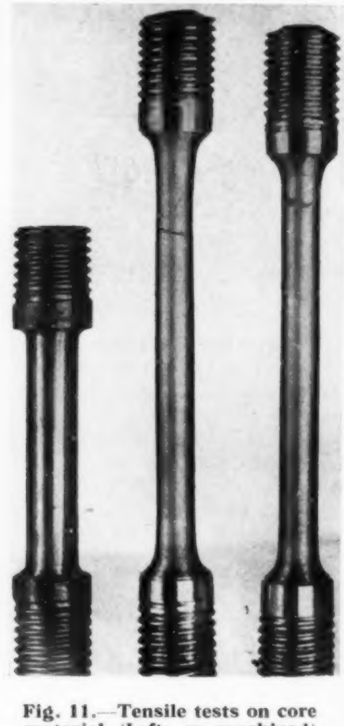


Fig. 11.—Tensile tests on core material (Left—as machined) showing small amount of "necking" at the fracture.

Fig. 9.—Withdrawing the core.

through the rolls. As regards the reduction and change of section after each pass, reference to Fig. 6 shows the form at each of the 20 stages of rolling a typical size, namely 1 in. hexagon.

Cooling After Rolling

Fig. 7 shows the method of cooling the steel on the hot bed after rolling. The purpose of this operation is to provide a uniform and comparatively rapid cooling rate to develop a suitable micro-structure and hardness, and at the same time reduce warping so that subsequent machine straightening will be kept to a minimum.

Extracting the Cores

The removal of the cores is comparatively straightforward, provided the temperatures employed for rolling, the rolling itself, and the properties of the core material have been properly controlled.

Fig. 8 and Fig. 9 show, respectively, the method of snicking the drill steel with a thin abrasive wheel, and the manner in which the core is withdrawn. The former provides a nick around the bar and enables the operator to fracture the drill steel without damaging the core. The jaw mechanism on the draw bench then grips the end portion as shown, and the core is pulled in tension until it ultimately fractures.

During the elongation preceding actual fracture, the diameter of the core is reducing progressively so that at the moment of rupture it is no longer a tight fit in the bore of the drill rod and therefore can be manually withdrawn without difficulty.

To show this reduction in core diameter more clearly and to illustrate the properties of the austenitic core steel Fig. 10 and Fig. 11 are included. In Fig. 10 a comparison is shown between core diameter and the bore of the drill steel, before and after the core has been extracted. It will be seen that at this stage withdrawal may be accomplished by hand, since the core is generally at least $\frac{1}{32}$ in. less in diameter than the size of the hole in the drill steel itself.

Fig. 11 shows standard core steel tensile tests after fracture. The considerable degree of elongation and the small amount of reduction in area at the point of fracture should be noted. These two test pieces were the same in size as the left-hand specimen in the photograph before commencing the test.

Fig. 12.—Straightening the bars.

Fig. 13.—Inspection bed.

Straightening, Checking, Bundling, etc.

When the core removal is completed, the steel is transported to the straightening machines. Reeling machines are used for round bars and roller straightening machines for hexagon and quarter octagon bars. The latter type machine is shown on Fig. 12. The steel is then transferred to the inspection beds, which are shown in Fig. 13. At this location the bars are checked for size with a snap gauge and tested with a compressed air jet through the hole to disclose any pieces of broken core rod or other restriction that may otherwise remain undetected.

The steel is then oiled to retard rusting during transit and storage, and finally bundled and painted on the end with a yellow identifying colour brand prior to despatch from the works.

In the concluding part of this article, to be published next month the author will deal with the heat treatment of mining drills and the types of failure encountered in service, including those due to fatigue, corrosion fatigue, faulty thermal treatment and faulty operation of the drilling machine.

Rapid Expansion of Metalock

Major E. C. Peckham, Managing Director of Metalock (Britain) Ltd., is now on the last lap of a 20,000 mile business tour. Following the establishment of offices in Amsterdam and Legnano, near Milan; Drammen, Norway; Gothenburg, Sweden; Moshi, Tanganyika; Dublin and Glasgow, all of which are superintended by the London headquarters, Major Peckham has now arranged for agencies in India, Pakistan, France, Portugal, the Iberian Peninsula, the Union of South Africa and Australia. In the last three centres limited companies are to be established shortly. There are already, of course, Metalock agents in South Wales, Grimsby, Newcastle and Manchester.

The Metalock process of cold repair to iron castings is being widely used by industrialists and shipping companies all over the world, and because repairs can be carried out on the spot, without the dismantling of machinery, much time and money is being saved.

Conflicting Views on Engineering Exhibitions

SIGNS are not wanting at the present time that there is a feeling on the part of certain prominent British makers that the machine-tool exhibition scheduled to take place in London in 1952 should be postponed in view of the pre-occupation of makers with the steady growth of orders in hand. As contrasted with certain other countries, the British engineering industry in general has never been particularly exhibition-conscious. For instance in Great Britain, machine-tool exhibitions have only been held at infrequent intervals during the last quarter of a century, whereas one may find quite a different attitude in continental countries; for the same industry in Belgium has since 1946 officially taken part in more than thirty machine-tool shows and exhibitions in various countries. That this policy seems to rest upon sound premises can be judged from the fact that no less than 80% of its output is exported.

Divergence of Views

Within the limit of the industry itself, however, there is to be found a wide divergence both of views and interests on the subject of exhibitions. The larger and better established firms are inclined to regard these gatherings as unnecessary evils, the feeling being that their own products are sufficiently well-known and their own position sufficiently secure as to make the expense of an exhibition, even for another twelve or fourteen years, largely superfluous, and in this connection it is, after all, the larger and more successful firms which mainly control the policy of the industry of which they are part. Smaller types of "up and coming" firms, however, do not take the same defeatist views as to the usefulness of an exhibition, and in this connection it has to be borne in mind that there are, in the machine-tool industry especially, numbers of makers who to all intents and purposes were practically unknown twenty years ago, and who feel that given the stimulus of exhibition and demonstration in suitable centres over a term of years, their own products would in the natural course of evolution reach the same position as is held by their larger and older-established competitors to-day.

Character of Exhibits

There is also to be found within the industry a further wide divergence of views on the character which an individual exhibit should take, and much of the inconclusive arguments for or against a particular gathering are due to a fundamental difference of opinion as to what should constitute an adequate exhibit. In this connection, the small-tool industry is extremely well situated, and a decision to exhibit can be taken almost overnight, and the following day, thanks to the resources of current stocks and the contents of standard showcases, 90% of the required exhibits can be ready for display. On the general engineering and machine-tool side, however, there is a general opinion that an exhibit is not worthy of the name if merely standard products are shown, and it is this mistaken desire for novelty at all costs which leads to such decisions that an exhibit must comprise at least a couple of machines of mammoth size, the castings for which will probably have disorganised the foundry for many months, and whose subsequent erection and transport tax to the utmost the facilities of the makers' works and the resources of the railways and transport contractors. Or again, if a 6-spindle machine has been the normal unit upon which the maker's reputation has been established for many years, it is far too usual to endeavour to astound intending customers and competitors by the production of a 12-spindle machine. If a horizontal machine has been the regular product in the past, then for the exhibition let the resources of the works be taxed to provide an entirely new vertical model, and so on. It will be appreciated that in establishments where ideas and policy of this description hold sway, the mere idea of an exhibition is apt to partake of a nightmarish quality, under the influence of which the regular manufacturing programme becomes blocked and disorganised, and chaotic hindrances are placed in front of the simplest and most routine of everyday tasks.

The Simple Exhibit

For the exhibitor, however, who has a standard product which he desires to make known, and who has determined that his exhibit will consist solely and exclusively of the type of machine which he is building and marketing successfully, an exhibition, whether in this country or abroad, can be regarded calmly and without any of the mixture of disorganisation and despair which, to judge from certain public pronouncements in the past, is the frame of mind which characterises many possible participants when the mere mention of a possible exhibition is made. Such a firm would merely take machines from its standard manufacturing programme, secure in the knowledge that for a fortnight's show, given reasonable organisation, the total delay in final delivery of the few standard machines involved could hardly exceed some five or six weeks, while ideas and achievements in the way of the gigantic and the unusual will be relegated to photograph albums and similar displays, which will be sufficient to show the curious visitor the feats in the way of the unusual which this particular maker may have achieved in the past and of which his organisation still remains capable, assuming the need or the opportunity for embarking upon such projects.

Cycle of European Machine-Tool Exhibitions

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Conflicting Views on Engineering Exhibitions

SIGNS are not wanting at the present time that there is a feeling on the part of certain prominent British makers that the machine-tool exhibition scheduled to take place in London in 1952 should be postponed in view of the pre-occupation of makers with the steady growth of orders in hand. As contrasted with certain other countries, the British engineering industry in general has never been particularly exhibition-conscious. For instance in Great Britain, machine-tool exhibitions have only been held at infrequent intervals during the last quarter of a century, whereas one may find quite a different attitude in continental countries ; for the same industry in Belgium has since 1946 officially taken part in more than thirty machine-tool shows and exhibitions in various countries. That this policy seems to rest upon sound premises can be judged from the fact that no less than 80% of its output is exported.

Divergence of Views

Within the limit of the industry itself, however, there is to be found a wide divergence both of views and interests on the subject of exhibitions. The larger and better established firms are inclined to regard these gatherings as unnecessary evils, the feeling being that their own products are sufficiently well-known and their own position sufficiently secure as to make the expense of an exhibition, even for another twelve or fourteen years, largely superfluous, and in this connection it is, after all, the larger and more successful firms which mainly control the policy of the industry of which they are part. Smaller types of " up and coming " firms, however, do not take the same defeatist views as to the usefulness of an exhibition, and in this connection it has to be borne in mind that there are, in the machine-tool industry especially, numbers of makers who to all intents and purposes were practically unknown twenty years ago, and who feel that given the stimulus of exhibition and demonstration in suitable centres over a term of years, their own products would in the natural course of evolution reach the same position as is held by their larger and older-established competitors to-day.

Character of Exhibits

There is also to be found within the industry a further wide divergence of views on the character which an individual exhibit should take, and much of the inconclusive arguments for or against a particular gathering are due to a fundamental difference of opinion as to what should constitute an adequate exhibit. In this connection, the small-tool industry is extremely well situated, and a decision to exhibit can be taken almost overnight, and the following day, thanks to the resources of current stocks and the contents of standard showcases, 90% of the required exhibits can be ready for display. On the general engineering and machine-tool side, however, there is a general opinion that an exhibit is not worthy of the name if merely standard products are shown, and it is this mistaken desire for novelty at all costs which leads to such decisions that an exhibit must comprise at least a couple of machines of mammoth size, the castings for which will probably have disorganised the foundry for many months, and whose subsequent erection and transport tax to the utmost the facilities of the makers' works and the resources of the railways and transport contractors. Or again, if a 6-spindle machine has been the normal unit upon which the maker's reputation has been established for many years, it is far too usual to endeavour to astound intending customers and competitors by the production of a 12-spindle machine. If a horizontal machine has been the regular product in the past, then for the exhibition let the resources of the works be taxed to provide an entirely new vertical model, and so on. It will be appreciated that in establishments where ideas and policy of this description hold sway, the mere idea of an exhibition is apt to partake of a nightmarish quality, under the influence of which the regular manufacturing programme becomes blocked and disorganised, and chaotic hindrances are placed in front of the simplest and most routine of everyday tasks.

The Simple Exhibit

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chromium and cobalt, with various additions of molybdenum, tungsten, niobium and titanium. They also examined a large variety of proprietary alloys of complex compositions, and set in hand investigations of an entirely new alloy series based on chromium, tungsten, titanium and cobalt. Emphasis was placed on much higher temperatures for the blades (816° C.) and discs (649° C.) and many of the promising materials were tested at temperatures above 816° C., but not in the lower ranges of temperature.

The situation revealed in Germany at the end of the war was very different. There, the need to economise scarce metals had controlled events. To conserve nickel, much attention was given to the austenitic chromium-manganese steels, hardened with small additions of vanadium, tantalum or molybdenum. In some steels intentional additions of nitrogen were made. A further conservation of alloying elements resulted from the use of air-cooled blades which allowed 18 : 9 and 16 : 15 chromium-nickel steels to be used, stabilised and stiffened with small additions, rarely above 2%, of molybdenum, tungsten, tantalum, titanium and, later, vanadium (in place of tungsten and molybdenum).

The properties of the alloys that were relied upon in each country were presented, in a series of graphs, in terms of the stresses giving plastic deformations of the order of 0·1% in 1,000 hr.

Dr. Allen's survey was aimed at giving a balanced picture of the progress at the end of the war, when emphasis had been almost exclusively on short-lived engines for aircraft. Although the alloys were developed in haste for such purposes, they were proving to be reliable over the longer periods of service and under the new conditions obtaining in longer life engines.

Supplier Aspects

The papers presented under this heading were :—

Nickel-Chromium-Titanium Alloys of the Nimonic 80 *Type.* By L. B. Pfeil, N. P. Allen and C. G. Conway.
Some Proven Gas-Turbine Steels and Related Developments. By D. A. Oliver and G. T. Harris.
Effect of Warm-Working on an Austenitic Steel. By G. T. Harris and W. H. Bailey.
Development of a High-Temperature Alloy for Gas Turbine Rotor Blades. By G. T. Harris and H. C. Child.
Properties of Materials Intended for Gas Turbines. By H. W. Kirkby and C. Sykes.
Study of the Properties of a Chromium-Nickel-Niobium Austenitic Steel. By H. W. Kirkby and C. Sykes.
Creep-Resisting Ferritic Steels. By E. W. Colbeck and J. R. Rait.
Ferritic Steels for Gas Turbines. By H. H. Burton, J. E. Russell and D. W. Walker.
Special Steels for Gas Turbines. By W. E. Bardgett and G. R. Bolsover.

The rapporteur, Dr. H. Sutton, observed that all the papers in the group had come from experts in the branches of industry engaged in the production of gas turbine alloys and components. Pfeil, Allen and Conway had given the story of the development of alloys of the Nimonic 80 class which had been used most effectively for turbine blading. They described their efforts to strengthen up an alloy of a type known to possess considerable strength and good resistance to scaling at temperatures up to 800° C., studying the effect of additions of titanium and aluminium together on forgeability and heat-treatability. Having obtained guidance on levels, they proceeded to study the effects of heat-treatment on the creep resistance and machinability of experimental alloys, the later stages of the work culminating in the supply of Nimonic 80A to a creep performance specification.

In the paper by Harris and Child, a clear account was presented of a study of the effect of carbide forming elements in nickel-cobalt-chromium alloys. A study of the effect of varying the nickel, cobalt and iron contents in alloys containing 70% of those elements, with 19% chromium, carbide formers and carbon, indicated the importance of fairly high cobalt content. As a result of work described in the paper, the authors showed how they arrived at the composition and heat treatment of G32. The results gave interesting indications of the carbide-forming power of the various elements and on the complex carbides present in various alloys and their influence on high temperature properties.

The first of the two papers by Kirkby and Sykes gave a useful summary of extensive experience in the fields of alloys and forgings in the ferritic materials—molybdenum–vanadium steels ; 3% chromium–molybdenum-tungsten–vanadium steel ; and 10–12% chromium steel—and in austenitic steels—FCB(T), an 18 : 12 steel stabilised with niobium ; 326 steel, a more complex austenitic steel containing molybdenum, niobium and chromium, suitable for use up to 720° C. ; and 337 steel, a complex austenitic steel containing additions of cobalt (7%), molybdenum, copper and titanium and having superior creep properties to the other two. A timely contribution was the information given on an austerity austenitic steel free from cobalt and niobium. A valuable feature of the paper was the discussion of the practical problems of producing large forgings in relation to the properties in the forgings.

In their second paper, these authors gave an account of their research and development work on FCB(T), discussing the creep performance in the light of mechanical and metallographic investigations, including the effect of recrystallisation, sigma phase, and availability of precipitating material. They reached the interesting conclusion that heat-treatment was the major factor, rather than grain size *per se*, affecting creep performance after heat-treatment.

Bardgett and Bolsover described their investigations of the multi-alloy type of steel, which they studied by omitting the various special added elements in turn in creep tests at 650° C. In the study of the full-composition alloy the effects of degree of hot reduction, direction of testing, and heat-treatment, at normal temperature and 650° C., were investigated. Work on a 25 : 15 chromium-nickel steel and a 20 : 30 : 1·2 chromium-nickel-titanium steel which had been used for flame tubes was also described including, for the titanium bearing steel, the dimensional stability at elevated temperatures and the effect of re-heating, with and without stress, on embrittlement. The results indicated the importance of the initial condition of the steel.

Information on heat-treatment, creep properties (including long-time tests) and general features of G18B, an austenitic steel which had been extensively used for jet engine discs, was given by Oliver and Harris, together with a brief treatment of a simple austenitic steel (19 : 14 with 1·7% niobium) intended for use at slightly lower temperatures (about 600° C.). In discussing the relative merits of austenitic and ferritic discs, the authors anticipated considerable future for the 12% chromium steel with small additions. Other parts of the paper dealt with turbine blade production, scaling as influenced by the products of combustion of the fuel,

and general factors affecting progress and general trends of development.

HARRIS and BAILEY recorded their studies of the effect of warm-working on G18B discs, including creep tests on warm-worked material up to about 10,000 hours. Warm-working enabled attractive tensile properties to be achieved in discs at the same time as improved creep properties at temperatures likely to be encountered at the rim.

In the paper by BURTON, RUSSELL and WALKER, studies of three types of ferritic disc steel were described, one of which (3% chromium-vanadium-tungsten) had been used extensively for jet engine discs, and another (molybdenum-vanadium) for parts of steam turbines. The authors discussed heat-treatment variations and their effects on creep and other properties.

COLBECK and RAIT also considered the relative merits of ferritic and austenitic steels and discussed the leading features of a number of low alloy steels including a 1% chromium-molybdenum steel and a 3% chromium-molybdenum-vanadium steel. Of particular interest was their work on the effect of composition and treatment on the latter steel to which small amounts of tungsten had been added, and their observations on the important and predominating effect of vanadium carbide in relation to creep properties up to 650° C. The influence of the various individual elements was discussed in the light of present knowledge gained in their own research work and that of other workers.

Discussion

SIR WILLIAM GRIFFITHS, in opening the discussion, expressed the hope that speakers would not concern themselves too much with details but deal with the broad aspects of the subject. Where an alloy having good high temperature properties, but capable of being hot-worked, was required, precipitation hardening properties seemed to be essential; it would be interesting to have views on the likelihood of precipitation hardening continuing to be of importance in the development of high temperature properties. There seemed to be two methods of using the phenomenon, employing, respectively, a single precipitant, and a number of possible precipitants which had to be balanced one against the other. From the point of view of producing regular reliable materials in quantity, there was much to be said for an intensive effort towards simplification. A further point raised by Sir William concerned negative creep, and while there were objections, on the grounds of stability, to using a change in the alloy, the matter was worthy of further consideration.

DR. W. SIEGFRIED (Sulzer Brothers, Switzerland) pointed out that for machine components, there were, under certain circumstances, multi-dimensional stressing, notch effects and certain parts which were subject to cold deformation. For that reason, other viewpoints than those for investigating smooth specimens must often be considered in selecting steels to be used for parts which must remain stable at high temperature. A particularly important aspect in gas-turbine design was the blade root fixing. In order to determine the permissible loading and the correct dimensions of the blade root, his company's procedure included (1) room temperature tests, (2) photoelastic tests, and (3) sustained load tests at service temperature—all carried out on blade root models, (4) tests on notched test pieces with differing notch forms, to determine the notch sensitivity and the relation between the local stress increases in the blade root and the tests with smooth and notched specimens. Dr. Siegfried showed a series of slides showing that notch sensitivity was dependent on the precipitation taking place and could change during the course of a test. A further series concerned experiments on the effect of cold deformation in the course of which it was established that different steels could react differently to cold deformation.

The importance of the thermal conductivity in determining the temperature at which different parts of the engine operated gave point to the remarks of DR. R. W. POWELL (National Physical Laboratory) who showed how values of that property could be predicted to a fair extent by the much simpler measurement of the electrical conductivity. After outlining the progress of attempts at correlation over the last 15 years or so, Dr. Powell showed a graph giving the latest position. This consisted of two lines representing the relationship between thermal and electrical conductivity, one for austenitic steels and the other for ferritic steels with the 13% chromium type of steel presenting something of an anomaly at lower temperatures. In all cases, the agreement was better at the higher temperatures.

Brief reference to the findings of his Company on the developments of large ferritic forgings for high temperature service was made by MR. J. MOWAT (Wm. Beardmore & Co. Ltd.). Work on the 3% chromium-molybdenum-vanadium-tungsten steel showed that the essential feature was the high vanadium content and that tungsten could be omitted for many purposes. On the molybdenum-vanadium class of steel, investigations had shown that increasing molybdenum and vanadium above 1% and 0·5%, respectively, did not appear advisable, but low carbon (0·2% max.) and up to 1% chromium were beneficial. By quenching with high-pressure water jets in a special apparatus in which the forging was rotated, followed by a high temperature tempering operation, fairly large stable rotors with good creep and other mechanical properties had been produced.

Disappointment at the lack of speculation on the mechanism of creep was expressed by DR. W. BETTERIDGE (Mond Nickel Co. Ltd.). It was generally accepted that creep could occur as the result of (1) slip within the grains, and (2) viscous or quasi-viscous flow at the grain boundaries. If the grains were perfectly elastic, grain boundary flow could only occur to a limited extent before the restraint of the grains prevented further flow. One could, therefore, expect a creep curve asymptotic to a fixed value of strain which would depend on the grain size. If, however, the grains flowed, due to a slip process, an additional progressive strain could be observed. The softer the grain at the test temperature, the greater would be the strain component due to flow and the less dependent would be the creep on grain size. With fully hardened material, grain flow would be less important, particularly in the early stages, before appreciable stress concentrations had developed, and the rate would be dependent on grain size, a conclusion which seemed to be supported by Fig. 11(d) in the second paper by Kirkby and Sykes. An investigation of the viscosity at the grain boundaries would appear to be likely to yield results of considerable importance.

MR. J. GLEN (Colvilles, Ltd.) emphasised the danger in using short-time tests to assess the relative behaviour of steels in long-time service. It was true that to explore every alloy completely would tie up an excessive number

of creep testing machines for very long periods. It was, therefore, most essential that some method of indicating quickly the alloys likely to possess good creep properties should be developed. Mr. Glen believed that could be done without the use of a creep machine, and presented results of high-temperature tensile tests carried out on a number of normalised steels under closely controlled conditions. The results provided an explanation of some of the anomalies in short-time creep tests. If creep testing were carried out for a short time at high stress, so that a considerable amount of deformation took place rapidly, steels which had the maximum work-hardening capacity would behave best, that is, in the normalised condition. On the other hand, at a low stress, the tempered steel might be better due to its high elastic limit. It was not sufficient merely to obtain a high elastic limit by bringing about precipitation, the precipitate should persist in an unaltered condition at service temperatures. Information on structural stability could be obtained on specimens subjected to long-time tempering treatments. Although the important constituent in an alloy was that precipitating at the highest temperature, the presence of other elements was necessary to ensure the maximum precipitation of the essential constituent ; this was shown in the paper by Colbeck and Rait. Mr. Glen concluded by reference to a steel which had been developed for making into pipe. It was a molybdenum-vanadium-titanium steel whose properties indicated that for long-time service it was possible for a simple ferritic steel to have properties comparable with a much more highly alloyed austenitic steel. It was not scale resistant, but it could be protected by a chromising treatment.

The mathematical aspect of creep testing was the subject of a contribution from MR. A. GRAHAM (National Gas Turbine Establishment) in which he outlined the progress of an attempt to deduce relationships whereby a prediction of the creep behaviour of a material could be made on the basis of high-temperature tensile tests performed at a constant rate of straining. Whilst they had still a long way to go, there was reason to hope that such an approach would give some clue to the utility of short-time elevated temperature tests.

MR. H. J. GOLDSCHMIDT (B.S.A. Group Research Centre) referred to the use of X-ray analysis in the investigations of heat resisting steels. The lattice dimensions of the austenitic matrix of G18B type steels was very sensitive to heat treatment and could indirectly disclose the precipitation of compounds even before their patterns became visible. Other contributions of X-ray analysis of the matrix concerned warm-working and the guaranteeing of a fully austenitic steel after treatment. The main contribution of X-ray analysis, however, lay in the study of carbide and compound constitution. An important step was the discovery of a ternary silicide of iron and niobium as a major constituent, which indicated that silicon was comparable in importance with carbon in niobium bearing steel. Mr. Goldschmidt then outlined the salient points which had emerged from his work on carbides and intermetallic compounds.

DR. K. W. ANDREWS (United Steel Companies, Ltd.) commented on the observations by Kirkby and Sykes on the constitution of steel containing niobium. Their own experience confirmed the authors' findings on precipitation of chromium carbide, even when there was enough niobium there to stabilise it, and on the formation of sigma phase. With steels of that type, even with a reasonable amount of carbon present, and a small amount of niobium—about 1%—a niobium-containing intermetallic compound was found and Dr. Andrews thought it possible that, in the alloy steels there were several different types of intermetallic compound whose nature and influence on creep was not fully understood.

MR. S. T. HARRISON (Armstrong-Siddeley Motors, Ltd.) welcomed Dr. Sutton's remarks on the importance of economy and machinability and the development of ferritic steels which could be used up to 650° C. represented a real achievement, as did the high-strength austenitic steels which did not rely for their properties on the presence of the more expensive elements. Since their inception, the Nimonic alloys had dominated the British aero-engine on the blading side. One of their most important features had been the reliability of production batches to give the high properties specified. The high stresses in a turbine blade arose, with well-designed combustion chambers, in the cooler part near the root, and it was for that reason that the properties of Nimonic alloys in the lower temperature ranges were of equal importance with those at 800° C. Mr. Harrison drew attention to the importance of keeping temperatures below specified limits due to the properties of Nimonic alloys dropping considerably when the boundary of the single phase region was reached. Finally, Mr. Harrison said that experiments had shown that the only type of abuse which the alloys did not appear to stand was considerable plastic strain, but even that had to extend over the whole section of the test piece and he concluded that Nimonic 80A had the capacity of standing up to the type of abuse which was liable to be experienced in the aero gas turbine.

Special Casting Techniques

The papers presented under this heading were :—

Centrispun High-Alloy Steel Aero-Engine Components.
Part I—The Centrispinning Process. By A. E. Thornton.
Part II—Physical and Mechanical Properties of Centrispun Die Castings. By J. I. Morley.
Centrifugal Steel Castings for Gas Turbines. By J. Taylor and D. H. Armitage.
Investment Casting of Nozzle Guide Vanes. By H. E. Gresham and A. Dunlop.
Precision-Casting of Turbine Blades. By E. R. Gadd.

DR. T. A. TAYLOR (N.G.T.E.) who acted as rapporteur for this group of papers, outlined the salient features of each in turn.

Part I of the paper by Thornton and Morley gave a general account of the centrispinning process and its application to gas turbine components in austenitic heat-resisting steels. The advantages of the process, which were most clearly demonstrated when metal moulds were used, included (*a*) freedom from porosity, (*b*) freedom from directional and centre weakness, (*c*) flexibility to accommodate complex designs, and (*d*) the ability to use alloys which were difficult to forge. Castings made in metal moulds were freer from inclusions than those made in refractory moulds, and the smaller grain size resulted in better mechanical properties. The conditions under which components would have to operate demanded a high standard of inspection ; the main defects encountered in production were surface laps, hot tears and porosity in the bore. The surface of centri-die castings (metal mould) was machined, and that of more complex shapes ground, before applying hot pickle, paraffin and chalk or fluorescent crack tests, the

first-named being preferred. Additional defects, such as internal porosity and occluded matter, arising in castings made in refractory moulds, necessitated additional tests by radiographic and supersonic techniques. When produced under careful control, remarkably uniform mechanical properties could be obtained.

Part II of the paper was concerned with the physical and mechanical properties of centri-die castings in FDP, FCB(T) and H.R. Crown Max steels. The pronounced radial columnar structure was found to have an appreciable effect on Young's modulus. Microscopic investigations showed that FDP solidified as delta-ferrite which largely transformed to austenite on cooling, some 1% of ferrite being retained at room temperature after cooling from 1,050° C. FCB(T) was fully austenitic from solidus to room temperature, and niobium carbide was deposited at the grain boundaries and between dendrites. The carbides appeared to be relatively insoluble in the austenite but the carbide phase fused at 1,300° C. With H.R. Crown Max (Type III) some ferrite was present on solidification, about 1% being retained at room temperature. Carbides began to precipitate at 1,100° C. and at room temperature some 5% was present around the ferrite pools, rather than at the grain boundaries. Creep and stress-rupture tests were confined to H.R. Crown Max. In a most interesting appendix to the paper, the effect of small changes in composition on the structure and properties of the H.R. Crown Max type of alloy was discussed.

In the paper by Taylor and Armitage, attention was focused on the production of thin walled components by centrifugal casting, the outstanding problem being the development of a mould material resistant to high temperatures and erosion by molten metal without causing hot tearing. An oil-bonded silica sand coated with a refractory wash was finally found to give satisfactory results. The manufacturing process was described in some detail, one of the key features being the breaking down of the design into simple shapes which could be moulded on a repetition basis. Prototype castings were investigated thoroughly before production commenced and a high standard of inspection was imposed. For use at elevated temperatures, three types of material were employed, (1) an 18 : 8 : 1 chromium-nickel-niobium steel, (2) a 25 : 12 : 3 chromium-nickel-tungsten steel, and (3) a nickel base alloy containing 80% nickel and 15% chromium.

Gresham and Dunlop described the use of the lost-wax process for the production of nozzle guide vane castings and outlined the main differences from ordinary sand foundry technique. Following a detailed description of production technique and recommendations on waxes, refractories, etc., the authors discussed their experiences in the production in austenitic steel of nozzle guide vanes varying from 0·5 oz. to 2 lb. in weight. They pointed out that the dimensional accuracy of the castings was affected by wax pattern shrinkage, by expansion of the refractory mould on heating, and by metal contraction. The degree of accuracy depended on the shape of the casting but could generally be held to ± 0·005 in./in. Of particular interest were the creep and rupture data given for various alloys in the temperature range 800–1,050° C.

The concluding paper by E. R. Gadd also described in detail the lost-wax process and discussed the relative merits of competing procedures at various stages. The author's Company specialised in the production of stator segments consisting of a number of blades joined together. A most interesting section of the paper dealt with the casting defects most likely to be encountered with the process and the means of preventing them. They included shrinkage cavities, cold shuts, and surface defects arising from a variety of causes. Mechanical test results and hot fatigue properties of Nimonic 80, and G18B, in the form of investment castings, were presented.

Discussion

In opening the discussion Mr. P. H. Lawrence (B.S.A. Precision Foundry) said he had read the papers with considerable interest and, although he was primarily interested in investment casting, he would like to ask whether the authors of the papers on centrifugal casting had any experience of casting a number of investment moulds in that way. In the investment process the properties of the wax were most important and he wondered whether the authors had devised a series of tests for checking them. His own experience with plastic patterns had shown them to be inferior to wax in dimensional stability and accuracy from one model to another. There appeared to be considerable differences in procedure in the drying and baking of moulds and information on tests carried out to determine the period of drying necessary would be welcome. Mr. Lawrence stressed the importance of maintaining a reasonable degree of fineness of the sand used, otherwise cracking troubles were encountered.

Mr. Z. Z. J. Kosarski (Sheepbridge Castings, Ltd.) said he agreed with Mr. Thornton's views on the relative reliability of castings made in metal and in refractory moulds but he felt that, if anything, the mechanical properties of sound refractory mould centrifugal castings were better than those for centri-die castings. The proof stress was some 10% higher and the ductility, although lower, was adequate. Furthermore the large grain size might be beneficial in creep, a point on which information would be welcome.

Whilst agreeing with Mr. Thornton that castings produced in metal dies were cleaner, Mr. M. M. Hallett (Sheepbridge Engineering Co., Ltd.) differed on the reason. Although the author had attributed the non-metallic inclusions to friction between the rotating mould wall and the molten metal, the inclusion shown in the photomicrograph looked more like original sin in the metal. He believed that the higher spinning speed of the metal mould resulted in a more efficient centrifuging of inclusions. Turning to the second part of the paper, Mr. Hallett wondered whether the authors had any creep data on the 25 : 12 type of steel, with and without tungsten.

Mr. A. Dunlop (Rolls-Royce, Ltd.), in answer to Mr. Lawrence, said it was their practice to test waxes by determining melting point, injection shrinkage, and hardness at various temperatures, and carrying out a deformation test in bending, but the final test was to make an actual pattern and check that. The question of mould drying time was governed by a number of factors such as whether or not the gel reaction took place before putting in the drying room, and whether or not the moulding box was removed before insertion of the mould in the furnace.

Mr. A. E. Thornton (Firth-Vickers Stainless Steels, Ltd.), replying to Mr. Lawrence's query regarding centrifuging of investment castings, was of the opinion

that, provided the metal handling arrangements were satisfactory, and the job to be cast lent itself to directional solidification, there was much to be said for centrifugal instead of static casting, but the combination of circumstances mentioned seemed to arise only infrequently. Referring to the difference between metal- and refractory-mould castings, Mr. Thornton said he felt that the differences in mechanical properties were not such as to override the importance of reliability. In answer to Mr. Hallett's remarks on inclusions, it should be stated that the photomicrographs were taken from two halves of the same casting, half of the mould length being metal and the remainder refractory.

Welding and Machinability Aspects

The papers in this group comprised the following :—

Welding of Heat-Resistant Alloys in Sheet Form. By H. E. Lardge.

Weld-Metal Properties and Welding Characteristics of Two Austenitic Steels Used for Gas-Turbine Rotors. By E. Bishop and W. H. Bailey.

Machining Austenitic and Ferritic Gas Turbine Steels. By K. J. B. Wolfe and P. Spear.

Dr. E. C. Rollason (Murex Welding Processes, Ltd.), who acted as rapporteur for this group of papers, said the development of the gas turbine had brought the problem of welding heat resisting alloys very much to the fore. The paper by Lardge dealt with the technique developed for precision sheet metal work. As more powerful engines were developed, the thicker materials used had encouraged the adoption of fusion welding, with arc welding possessing advantages from the point of view of distortion. To date, however, resistance welding methods had been most widely used, and the author discussed in detail spot, stitch and seam welding and reference was made to the reduction of distortion by welding under water. The success of the processes was dependent on the accurate control of current, pressure, and the time sequence of operations. Reference was also made to a hot-riveting process, using a special type of spot welding machine, whereby work-hardening was avoided and a tight joint ensured by the contraction on cooling.

Turning to the paper by Bishop and Bailey, dealing with the welding of heavy sections, Dr. Rollason said that the rotors required for land and marine gas turbines were too large to be produced in a single forging and they had, therefore, been fabricated by welding from smaller forgings. The authors had carried out investigations on weldability, weld metal characteristics and the properties of welded joints in two austenitic steels, G18B and R20, using special electrodes. Although the use of a preheat of 600° C. was claimed by some to be helpful, the authors found it to make the welding operation difficult and uncontrollable. Welded assemblies should be stress-relieved at 650° C., experiments on heat treatment at 1,300° C. suggesting that although the heat treatment of welded G18B could be carried out without ill-effects it was not necessary. More difficulties were experienced in the welding of R20 (19% Cr, 13½% Ni, 1½% Nb) due to micro-cracking in the multi-run welds. This occurred under the following conditions : (*a*) the absence of delta-ferrite in the structure ; (*b*) the simultaneous presence of silicon exceeding 0·4% and niobium in excess of about 8 times the carbon content ; and (*c*) the reheating of earlier beads from 600° C. up to the melting point. A characteristic grain boundary precipitate formed was claimed to be an iron-silicon-niobium compound. A suitable weld composition was stated to be 0·3% Si, 0·12–0·16% C, and niobium 8–10 times the carbon content. The authors concluded that the welding of R20 did not markedly affect the creep strength and that welds could be put into service without subsequent heat treatment.

The third paper concerned the fundamental problems associated with the machining of heat-resisting and creep-resisting alloys, with special emphasis on the correct selection of conditions for maximum machine efficiency. The alloys being readily work-hardened, cutting must be continuous and the heat developed necessitated copious supplies of coolant. Consideration was given in the paper to the selection of tool materials and of cutting fluids, the addition of extreme pressure additions which acted mechanically being inadvisable for austenitic alloys. Basic considerations of machine design and machining conditions were discussed and suggestions made for improvement in machinability by (1) adding molybdenum, selenium, zirconium and sulphur to produce inclusions, and (2) by heat-treatment prior to machining. (Nimonic 80 was easier to machine when fully treated than in the softer solution-treated condition). Finally the authors suggested a number of future developments such as the reduction of the amount of machining by closer tolerances in forging, and by precision casting ; flash-butt welding of discs and solid-phase welding ; improved cutting materials and fluids ; and hot-spot machining and electrolytic cutting.

Discussion

Dr. H. G. Taylor (British Welding Research Association) opened the discussion by referring to the hot-spot method of machining and said that a report of some excellent American work had recently been published, in the publication of the American Society of Mechanical Engineers, in which it was concluded that the method had promise, particularly for materials such as those being considered. He was interested to note that Bishop and Bailey had been able to show that with both V and U joints the creep strength of the welded joints is, in many cases, as high as that of the parent metal. The high maximum stress of the deposited G18B alloy had been attributed to hardening taking place as a result of plastic deformation : might it not be that some sub-microscopic change was responsible ? Dr. Taylor referred to the influence of the low thermal conductivity of the alloys used in slowing down the rate of flow of heat away from the weld, and pointed out the possibility, in high speed resistance welding, that the materials might not be held together long enough to ensure that separation did not occur.

Mr. G. C. E. Olds (The British Thomson-Houston Co., Ltd.) added a further requirement in long-life gas turbine rotor welds to those enumerated by Bishop and Bailey—namely, that the weld should retain its ductility and toughness for long periods at the operating temperature. After observing the phenomenon of micro-cracking in niobium-stabilised 18 : 14 austenitic weld metal, they had turned their attention to the duplex welds of the 18 : 8 type, stabilised with niobium, containing a proportion of ferrite. Such welds whilst having good properties were embrittled by sigma phase formation when maintained for a long period at temperatures of the order of 650° C. A more recently developed weld metal of that type, containing 2% copper, retained to some extent the advantage of the duplex structure with considerably reduced high temperature embrittlement.

The important feature was that the ferrite content was of the order of 5%, as against 10–15% without the copper. In the figures given by the authors for all-weld-metal G18B and R20 tensile tests, the ductility appeared to have fallen considerably after one hour's annealing at 650° C. It would be interesting if the authors could give figures after maintaining at operating temperatures for long periods.

Further to Mr. Old's comments, MR. R. R. ROBERTS (B.T.H. Research Laboratory) said that metallographic studies had shown that in the normal 18 : 8 deposit, nearly all the 10–15% delta-ferrite changed to sigma phase after 1,000 hours at 650° C., whereas in the copper bearing type, only about half the delta-ferrite changed. It was this slower change, combined with the fact that complete change would not form the complete network experienced without copper, which accounted for the reduced embrittlement. There was no doubt, however, that close control of the composition of the deposit was essential for success. In their fully austenitic welds containing niobium, they had had cracked welds with lower silicon contents than the maximum quoted by the authors : the carbon contents were also lower and he wondered whether the formation of carbides might help to stop cracking in the same way as delta-ferrite. It was difficult to avoid weaving technique in large welds and micro-cracks might result in fully austenitic weld metal, even if they did not occur with straight runs. Towards the top of deep welds, cracking had been experienced in the parent metal, but careful design of the weld groove and limitation of the electrode size had largely overcome the trouble.

MR. H. J. GOLDSCHMIDT (B.S.A. Group Research Centre) said it was gratifying to find that his work on X-ray examination of G18B steels could be applied to tracing the causes of micro-cracking of weld deposits with high silicon contents. The ternary iron-niobium-silicide formed an embrittling grain boundary constituent, and in the presence of carbon, whether niobium formed carbide or silicide was a question of the balance of the elements.

PROFESSOR DR. ING. F. RAPATZ (Gebr. Bohler & Co., Austria) suggested that hot cracking was due to the weakness of intergranular substances which either had a low melting point or were weak at temperatures of 800–900° C.; when they became glassy. In order to avoid hot cracking the silicon should be low and the manganese high. Professor Rapatz said that, in his experience, acid steel was not so good as basic steel for such purposes.

Work on a steel closely related to G18B confirmed its crack resistance, said MR. J. I. MORLEY (Brown-Firth Research Laboratories). The fact that both steels were fully austenitic suggested that there were other ways of overcoming cracking troubles in austenitic welds than by introducing small amounts of ferrite. This type of steel was, however, subject to embrittlement due to exposure at high temperatures for long periods, but the effect could be minimised by attention to the welding technique. Varying degrees of cracking had been experienced with 18 : 13 steels stabilised with niobium and Mr. Morley presented evidence to suggest that the theory of low silicon content was not the practical answer to the problem. The practice seemed to be to rely on ferrite which could cause embrittlement if present in excess. They believed that small amounts of ferrite would actually reduce embrittlement by dispersing the carbide from the primary austenitic grain boundaries. Although the ferrite tended to reduce the creep strength of a weld deposit, this disadvantage was offset by the increased rupture-ductility. In conclusion, Mr. Morley refuted the statement that G18B-type welds had no anisotropic properties, as could be seen from the oval section obtained when a tensile test piece taken across the columnar grains was fractured.

MR. W. HUBER (Sulzer Brothers, Switzerland) dealt with welded rotors from the standpoint of the design engineer. Better properties could be obtained in the smaller forgings needed in welded construction, and greater reliance could be placed on inspection and testing. Furthermore there was a saving in time and money if only a small forging had to be rejected as defective. A reduction in cost could also be achieved by using steels suitable for the conditions operating at the various stages instead of that suitable for the highest temperatures throughout. The better properties enabled higher speeds to be used and, therefore, a smaller diameter, with consequent savings on other parts. The importance of thermal stresses due to rapid heating-up was discussed and Mr. Huber pointed out the advantages of ferritic steels in that respect. Correct design was very important for a welded rotor and the method of blade fixing had considerable influence on that point. Considerable investigation work had been carried out on the welding of rotors, and a number of service inspections of three G18B rotors in the 20,000 kW gas turbine at Weinfelden had shown no evidence of faults. The low-pressure rotor of that plant was a chromium-molybdenum ferritic steel, the welding of which had presented greater problems than those arising with austenitic steels, due to the transformation occurring on cooling from the welding temperature.

MR. H. E. LARDGE (Joseph Lucas (Gas Turbine Equipment) Ltd.) commented on the overlap required in resistance welding. Weight considerations frequently prevented the use of overlaps of the size generally regarded as most suitable for the best strength and fatigue properties. Mr. Lardge then gave figures for welding speeds with various materials, a very important factor in production. He emphasised that the precision sheet metal work in the combustion chamber was an integral part of the engine and suggested that investigations should be made into such questions as the fatigue properties of resistance and fusion-welded joints on thin sheet-metal work at elevated temperatures. In conclusion he hoped that the manufacturers of welding machines would note the efforts being made in America to obtain better welding by improved control circuits.

DR. E. C. ROLLASON said that in spite of the big improvement in resistance to micro-cracking given by the special R20 electrodes, he felt that the trouble was not always completely eliminated. Nor did he think the ternary compound provided a complete answer, as cracking had been obtained in niobium-free steels. They were about to publish an account of an investigation into the problem in which it would be suggested that micro-cracking was a fundamental problem concerned with the austenite grain boundaries above about 1,200° C. Any means of reducing the energy at the grain boundary, by packing in small atoms into the smaller spaces and big atoms into the bigger ones might increase the strength at which cracking occurred ; the effect of carbon and niobium in a fairly balanced ratio might be on those lines. Where complete stability against intercrystalline corrosion was not required, controlled ferrite

content of the deposit could be obtained by using molybdenum instead of copper and niobium. The copper-containing weld metal suffered a loss in ductility at about 850–1,000° C., and re-welding after stress relieving at 850–900° C. could result in cracking of a different character from that discussed in the papers.

Vitreous Enamelling Furnace Installation

ALTHOUGH many new methods of finishing ferrous metals have been introduced recently, the vitreous enamels have maintained their popularity. Within recent years, many new types of enamels have been formulated and, in conjunction with developments in modern processing methods and in the base metals themselves, the use of vitreous enamelling has extended to a large variety of consumer goods and industrial products.

Owing to the insistence nowadays on high quality finishes, and the large amount of plain colour and white work to be processed, cleanliness of operation is an essential feature of the furnace to be used. Fig. 1 illustrates two electric enamelling furnaces supplied by G.W.B. Electric Furnaces, Ltd. to Thomas De La Rue & Co., Ltd. The installation on the right was supplied in 1933 and is still functioning satisfactorily.

The furnace on the left in Fig. 1 was supplied towards the end of last year. It has an electrical rating of 180 kW, divided into two zones, each controlled automatically. The heating elements consist of heavy gauge ($\frac{3}{16}$ in. dia.) 80 : 20 nickel-chromium wire wound into $1\frac{3}{8}$ in. diameter coils, supported in specially moulded open groove refractory firebricks. Stress is reduced to a minimum by the method of continuous support whilst the open structure permits a maximum dissipation of heat and does not introduce any complications arising from shielding with its attendant excessive element temperature. The charge-supporting piers provide a firm base by reason of the retaining wall design of construction. Heating elements are fitted in these piers, suitably protected so that any accumulation of dirt forms on the bare refractory of the furnace hearth at the base of the piers and is thus easily removable.

For the purpose of loading and unloading the furnace, a Duplex hand-operated charging machine is in use. This machine is arranged for a limited traverse so that one section can be used for discharging while the other

Fig. 1.—General view of enamelling furnaces.

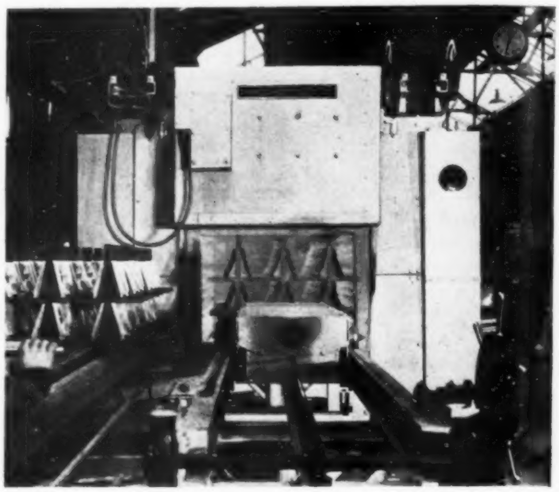


Fig. 2.—View of furnace unit with door raised.

half is loaded for charging ; the loading of the second half section of the machine may be effected while the first load is being processed. This arrangement cuts to a minimum the time when the door is open, a further saving being made by the speedy raising and lowering of the door which is fitted with heating elements to prevent end losses.

It is somewhat difficult to formulate specific data on outputs and power consumption in vitreous enamelling, due to the varying thickness of the base metals and the differing proportions of heat absorbed by the enamel itself and the actual metal being covered. As an example, when considering sheet steel 24 gauge (0·025 in.) thick, from which domestic articles are normally manufactured, the amount of electricity required to heat one square foot to 900° C. is 74 watts. Assuming an undercoat is applied, this by itself would absorb some 19 watts for both sides, while the enamel cover coat would require 23 watts for the temperature in question, making a total of 42 watts. It will be seen from these figures that the power required to heat the coating forms an appreciable percentage of the whole. An obviously important factor is the type of fixtures or perrits used for supporting the charge. These must be designed to have as little weight as possible consistent with sufficient strength, so that the amount of " unproductive metal " to be heated is reduced to a minimum. When used for enamelling cast iron gas cooker parts at about 800° C, the furnace illustrated gives an average output of some 6 lb./kWh.

Acknowledgments are made to Thomas De La Rue & Co. Ltd., and to G.W.B. Electric Furnaces, Ltd., for permission to use the information and photographs presented here.

Segregation of Iron and Manganese in Some Aluminium Casting Alloys*

By W. H. Glaisher, B.Sc., A.I.M.†

(*Communication from The British Non-Ferrous Metals Research Association*)

The results of investigations into the troublesome gravity segregation which may occur with alloys within or near to the specifications D.T.D.424 and L.A.C.112, due to the presence of undue amounts of iron and manganese, are presented, together with recommendations on composition limits and procedure to minimise this effect in the production of castings.

THE work to be described arose from variations in iron content observed in castings made from secondary aluminium alloys high in silicon, and consequent inferior properties in some parts of the castings. If iron and manganese are present in such alloys in sufficient amount, primary crystals relatively rich in these elements, and of higher specific gravity than the melt, may form at temperatures well above the "liquidus" at which the alpha aluminium solid solution begins to crystallise.‡ The sinking of these primaries in the liquid alloy results in gravity segregation. The temperature at which they begin to separate depends on the combined content of iron and manganese, in alloys otherwise similar in composition, and when this is sufficiently high, separation of iron-rich primaries may occur even above the pouring temperature. These primary crystals may then concentrate at the bottom of the crucible as well as in the lower parts of the casting.

Segregation in Castings

Slow cooling of the metal in the mould favours gravity segregation, since the primary crystals grow larger and have more time to sink than when cooling is more rapid. Segregation is thus more likely to occur in large sand castings and slowly cooled ingots than in small sand castings or die castings.

For studying the distribution of iron-rich constituents in castings, trials were made of "iron-prints" obtained by contact of machined surfaces with acidified paper impregnated with potassium ferro- or ferri-cyanide; useful consistent results were not obtained. The etching of machined surfaces was more successful. After degreasing, the specimen was immersed in a solution of 2% potassium ferricyanide and 10% sulphuric acid (by volume). Immersion for 10 minutes at 40° C. (or longer at a lower temperature) was usually sufficient to give a blue deposit adherent enough for the specimen to be washed in water and then in acetone and allowed to dry. The blue deposit was seen by low-power microscopic examination to consist of small stains locating particles of iron-rich constituents, and thus gave a clear picture of the distribution of iron segregation.

The alloys examined comprised 22 of the D.T.D.424§ type and 23 of the L.A.C.112|| type. The compositions laid down in these specifications are shown in the following table.

		Cu	Si	Mn	Fe	Mg	Ni	Zn	Ti
D.T.D.424	min. %	2·0	3·0	—	—	—	—	—	—
	max. %	4·0	6·0	0·7	0·8	0·15	0·35	0·20	0·2
L.A.C.112	min. %	2·0	7·0	—	—	—	—	—	—
	max. %	3·0	13·0	0·5	1·0	0·3	1·5	1·2	—

The alloys in the D.T.D.424 group complied with the specification in copper, silicon, nickel, magnesium and titanium content but the iron in most, and the manganese in some, of the alloys were above the limits specified. The percentages of these two elements are shown graphically in Fig. 2. Silicon ranged from 4·6–5·7%. The composition of the alloys in the L.A.C.112 group complied with the specification except that some contained more iron or manganese than is specified, the actual percentages being shown graphically in Fig. 3. Silicon varied from 8·1–12·5%.

D.T.D. test-bars, the feeder heads of which were 3 in. diameter sand castings, were cast at 700° C. from all the alloys; heads were sawn through axially and the cut surfaces were machined smooth. After degreasing these surfaces were etched as described above. Fig. 1 represents the appearance of an etched section. In some cases iron enrichment was found to a depth of about ¼ in. at the lower tapered part of the head and in the upper part of test-bar. In other cases iron enrichment extended nearly half way up the head. The straight line in Fig. 2 (silicon approx. 5%) connecting the compositions (iron 1·65%, manganese nil), and (manganese 1·1%, iron nil) is the locus of iron and manganese contents expressed by the equation Fe % + 1·5 Mn % = 1·65. With few exceptions this line divides the alloys showing gravity segregation from those which did not.

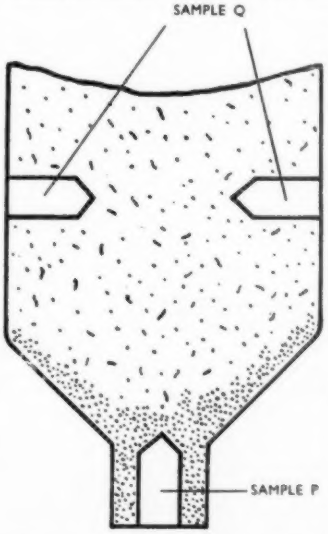


Fig. 1.—Diagrammatic representation of an etched section of a D.T.D. test-bar feeder head.

Similarly Fig. 3 (silicon approx. 11%) shows the

* *B.N.F.M.R.A.* Report R.R.A. 905 P. The work described in this paper was reported to *B.N.F.M.R.A.* members in confidential reports R.R.A. 593 and [illegible]7 issued in 1942–43.
† Formerly Investigator at the B.N.F.M.R.A., London. Now Metallurgist at the British Iron and Steel Research Association, Sheffield.
‡ "Liquidus" is used in this sense throughout the paper.
§ The new designation for D.T.D.424 is B.S.1490–LM–4.
|| Specification L.A.C.112 has since been replaced by L.A.C.112A which allows less latitude in composition.

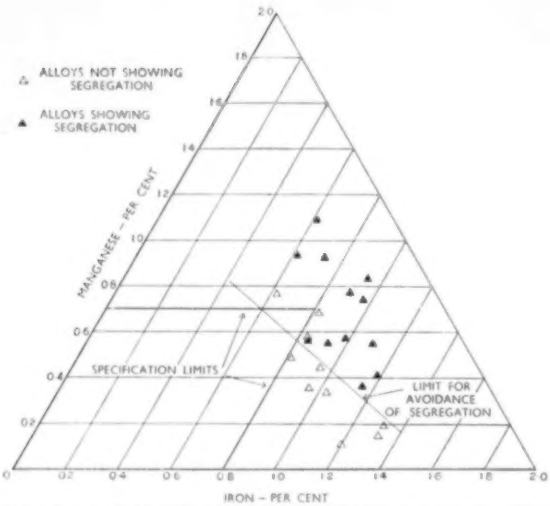


Fig. 2. Segregation in test-bar feeder heads in alloys containing approximately 5% silicon.

dividing line between segregated and unsegregated alloys as corresponding to Fe % + 1·5 Mn % = 1·5. These limits apply to D.T.D. test-bar heads; one experiment in which cooling through the solidification range was much slower gave gravity segregation when Fe % + 1·5 Mn % = 1·36.

Figs. 2 and 3 agree in their indications that manganese is more powerful than iron in causing gravity segregation and that their combined effect may be expressed approximately by the formula Fe % + 1·5 Mn %. The use of this formula is further supported by the later work to be described.

The following two examples are typical of the analytical figures given by samples taken from positions P and Q in Fig. 1 :—

Position		P	Q
Melt X	. . Iron %	1·25	0·71
	. . Manganese %	1·86	0·59
Melt Y	. . Iron %	1·39	0·93
	. . Manganese %	0·80	0·30

Segregation in Melts

In a series of preliminary experiments, eleven melts of weight 6–35 lb. were made from secondary alloys containing approx. 5 or 10% silicon, 2·5–3% copper, 0·8–1·5% iron, 0·4–0·7% manganese. The melts were heated to 800°–850° C., stirred and allowed to cool on the foundry floor to temperatures such as might be obtained towards the end of the pouring of a series of castings from one melt. Various methods of taking samples from the top and bottom of the melt showed a higher content of iron at the bottom, the difference in some cases being considerable, but trustworthy quantitative information on the extent of gravity segregation was not obtained on these relatively large melts.

Better success was obtained on small melts cooled under more closely controlled conditions in tubes. The alloys were meltec in crucibles and raised to 800° C. and portions transferred to $1\frac{1}{4}$ in. diameter steel tubes, thinly lined with alundum. The tubes were cooled slowly in an electric furnace in a vertical position, the depth of liquid alloy being 3–4 in., were held for a given time at the required temperature and then quenched in water. Solidification was complete in 5–10 seconds. Segregation was studied by etching axial sections or by analysis. Variations from this procedure are described below.

Three basis compositions were chosen for these experiments :—

	Alloy A	Alloy B	Alloy C
	%	%	%
Copper	3·0	2·7	2·6
Silicon	5·4	8·1	12·5
Iron	0·82	1·14	1·16
Manganese	0·69	0·52	0·52
Nickel	0·2	1·0	1·0
Zinc	0·2	1·0	1·0
Magnesium	0·1	0·25	0·25

Alloys of varying iron and manganese contents, otherwise similar to these three compositions, were prepared subsequently.

1. Alloys Slowly Cooled to Holding Temperature

The three alloys, in steel tubes as described, were slowly cooled from 800° C., held for 30 minutes at 670° C., 650° C., and 630° C. in separate experiments and quenched. Alloy C showed no segregation at any of these temperatures, and none of the three alloys showed segregation when quenched from 670° C. Massive particles at the sides of the ingots were observed in Alloy A quenched from 650° C. or 630° C., and in Alloy B quenched from 630° C. Samples from segregate-free positions of the ingots quenched from 630° C. were analysed and gave :—

	A	B
	%	%
Iron	0·59	0·92
Manganese	0·37	0·31

Alloys A and B held at 630° C. in magnesite tubes gave similar segregation of massive particles at the sides,

TABLE I.

	Composition of Alloy							Whether segregated, and Fe and Mn content at segregate-free positions		
	Cu	Si	Fe	Mn	Ni	Mg	Zn		Fe	Mn
"A" Series (5% Si) held at 650° C. for 30 minutes after slow cooling from 750° C.										
A	3	5·4	0·82	0·69	0·2	0·1	0·2	Yes	0·77	0·60
A2	3·2	5·6	0·79	0·42	0·15	nil	0·4	No		
A3	3	5·4	0·80	nil	0·2	0·1	0·2	No		
A4	3	5·1	2·3	0·63	0·2	0·1	0·2	Yes	1·41	0·29
A5	3·2	5·1	2·3	nil	0·2	0·1	0·2	No		
A6	nil	5·1	2·3	nil	nil	nil	nil	No		
"B" Series (8% Si) held at 630° C. for 30 minutes after slow cooling from 750° C.										
B	2·7	8·1	1·14	0·52	1	0·25	1	Yes	0·94	0·33
B2	2·7	8·0	1·10	nil	0·8	0·25	1	No		
B3	2·7	8·0	0·82	0·36	0·8	0·25	1	No		
B4	2·7	8·0	0·81	nil	0·8	0·25	1	No		
B5	2·7	7·5	2·3	nil	1	0·25	1	Yes	1·71	
B6	nil	7·5	2·3	nil	nil	nil	nil	Yes	1·75	
"C" Series (12% Si) held at 630°–645° C. for 30 minutes after slow cooling from 750° C.–600° C. and reheating to 640° C.										
C2	2·7	12·0	1·11	nil	0·8	0·25	1	No		
C3	2·7	12·0	0·82	0·42	0·8	0·25	1	No		
C4	2·7	12·0	0·79	nil	0·8	0·25	1	No		
C5	2·7	11·9	2·6	nil	1	0·25	1	Yes	1·41	
C6	nil	12·0	2·3	nil	nil	nil	nil	Yes	1·48	

showing that this effect is not caused by attack of the melt on the steel tubes. The position of the segregates may be due to nucleus action of slight irregularities in the bore of the coated steel tubes. Tapping the tubes during holding at temperature had the effect of shaking off these side segregates, which were then found at the bottom of the ingot.

Table I indicates the incidence of gravity segregation in alloys of different iron and manganese content but otherwise similar to A, B and C. The melts, in lined steel tubes, were cooled from 750° C. at 2° C. per minute, and finally quenched after the detailed treatment given in the table.

The results in the "A" series (5% silicon) reveal the controlling effect of manganese on gravity segregation. It appears that a manganese content over 0·6% caused segregation whether the iron content was 0·8 or 2·3%.

TABLE II.—ALLOYS REHEATED, AFTER COOLING AT ABOUT 8° C. PER MINUTE UNTIL SOLID.

Treatment	Alloy A	Alloy B	Alloy C
Held at 670° C., 5–10 mins. No stirring. Quenched.	0·59 Fe 0·33 Mn ½ in. layer of segregate at bottom	0·71 Fe 0·23 Mn ⅜ in. layer of segregate at bottom	0·87 Fe 0·25 Mn ¼ in. layer of segregate at bottom
Held at 670° C., 30 minutes. Stirred once, directly alloys reached 670° C. Quenched.	⅜ in. layer of segregate at bottom	3/16 in. layer of segregate at bottom	No segregation
Held at 700° C., 30 minutes. Stirred once, directly alloys reached 700° C. Quenched.	No segregation	No segregation	No segregation

NOTE.—The analyses given are of samples taken from the segregate free portions of the test ingots.

TABLE III.—ALLOYS REHEATED, AFTER COOLING AT ABOUT 2° C. PER MINUTE UNTIL SOLID.

Alloy	Initial composition			Analysis at positions in ingot free from segregation			
	Si	Fe	Mn	Fe	Mn	Fe	Mn
				Held at 670° C. 45 minutes with occasional stirring		Held at 630° C. 45 minutes. Stirred once	
A	5·4	0·82	0·69	0·72	0·33	0·55	0·36
A2	5·6	0·79	0·42	No segregation		0·67	0·28
A3	5·4	0·80	nil	No segregation		Not tested	
A4	5·1	2·3	0·63	1·50	0·33	Not tested	
A5	5·1	2·3	nil	2·09		1·66	
A6	5·1	2·3	nil	2·02		1·57	
				Held at 630° C. 45 minutes with occasional stirring		Held at 610° C. 45 minutes. Stirred once	
B	8·1	1·14	0·52	0·80	0·32	0·68	0·21
B2	8	1·10	nil	No segregation		Not tested	
B3	8	0·82	0·36	0·71	0·24	Not tested	
B4	8	0·81	nil	No segregation		Not tested	
B5	7·5	2·3	nil	1·56		1·31	
B6	7·5	2·3	nil	1·60		0·93	
B7	7·5	0·27	1·0	Not tested		0·14	0·50
				Held at 590°–600° C. 45 minutes with occasional stirring		Temperature varied between 560° and 600° C. 30–60 minutes. No stirring.	
C	12·5	1·15	0·52	0·69	0·23	0·62 0·68	0·17
C2	12	1·11	nil	0·80		Not tested	
C3	12	0·82	0·42	0·60	0·21	0·53 0·55	0·22
C4	12	0·79	nil	0·76		Not tested	
C5	12	2·6	nil	0·89		0·80 0·98	
C6	12	2·3	nil	1·37		0·78 0·88	
C7	12	0·48	0·86	0·17	0·39	Not tested	

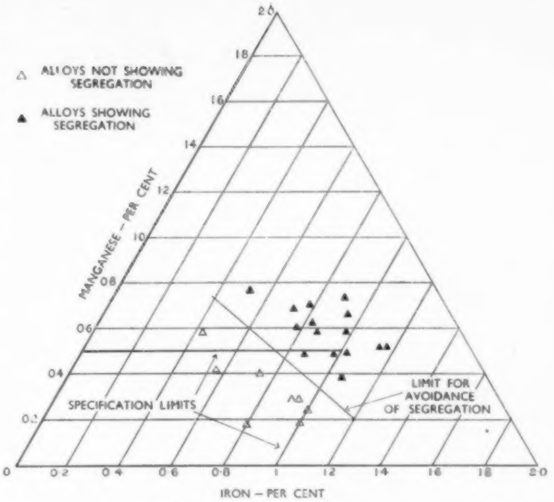


Fig. 3.—Segregation in test-bar feeder heads in alloys containing 8–12·5% silicon.

In the absence of manganese no segregation occurred even with 2·3% iron. For the 8% and 12% silicon alloys the treatment was more favourable to segregation, which occurred in the alloys containing 2·3% iron and no manganese, and in the alloy containing 8% Si, 1·1% Fe and 0·5% Mn.

2. Alloys Slowly Solidified and Reheated to Holding Temperature

The conditions of these experiments, similar to those occurring if a die-casting bath of an alloy were allowed to freeze and then reheated to a temperature a little above the "liquidus," were intended to promote gravity segregation strongly. Whether an alloy is homogeneous after such treatment depends not only on whether segregation occurred during the initial cooling, but also on the rate at which any segregate formed is redissolved on reheating; stirring also has an effect. The same lined steel tube technique was used; the liquid alloys were cooled slowly from 750°–800° C. until completely solid, then reheated as described in Tables II and III and quenched. The A, B and C series of alloys, whose compositions are given in Table I, were used.

Table II shows that the segregate separating on slow solidification is slow to dissolve on remelting. Only the 12% silicon alloy was free from segregation even after 30 minutes at 670° C.

The treatments of the 5% and 8% silicon alloys in the last column of Table III were at temperatures slightly above their "liquidus" and were thus very conducive to gravity segregation effects. The treatments in the first column were intended to ascertain the extent to which segregation persists at somewhat higher temperatures. The results given by B3 and C3 in Table III show that segregation may occur with iron and manganese contents well within the specification L.A.C.112 under conditions specially favouring gravity segregation. B7 and C7 show that segregation may occur with high manganese even when the iron content is very low.

In the treatment of the 12% silicon alloys in the last column of Table III the alloys were solidified and remelted two or three times before quenching, to

determine the reduction of iron possible by separation of segregate. The substantial decrease in iron content suggests that useful purification of such alloys may be secured by treatments of this kind.* The two figures given for segregate-free iron content are the highest and lowest obtained in several tests with slightly different temperature variations.

Discussion of Results

The main purpose of the experiments described was the practical one of determining the limits of composition of alloys, within or near the specifications D.T.D.424 and L.A.C.112, necessary for the avoidance of troublesome gravity segregation. No attempt has been made to investigate the thermal equilibrium of alloys of these types ; they are commonly made from secondary metals and often contain significant amounts of six to eight elements in addition to aluminium. The composition of the iron-manganese complex which first separates from the cooling melt has not been determined and it has not been possible to ascertain the precise maximum content of iron and manganese below which gravity segregation cannot occur in any circumstances. The results obtained, however, indicate the conditions for avoiding gravity segregation in these alloys in the practical manufacture of castings of different kinds.

Whether gravity segregation will occur in alloys within the composition limits specified in D.T.D.424 or L.A.C.112 depends on the content of iron, manganese and silicon and the thermal conditions of melting and casting. An indication of the pronounced effect of manganese on the limiting percentage of iron is obtained from alloy C7 in Table III containing 0·48% iron and 0·86% manganese. After treatment strongly favouring segregation the segregate-free portion contained only 0·17% iron with 0·39% manganese.

The iron and manganese contents of the segregate-free portion of a melt after any particular treatment may be used as an indication of the limits necessary for the avoidance of segregation under that treatment. The results obtained suggest that there is little or no danger of segregation in any practical conditions if the following limits are not exceeded :—

D.T.D.424.	0·6% iron with 0·3% manganese.
L.A.C.112, low silicon.	0·65% iron with 0·2% manganese.
L.A.C.112, high silicon.	0·5% iron with 0·2% manganese.

In each case with more manganese less iron would be allowable and vice versa.

The limiting iron and manganese contents for sand castings and gravity die castings will be considerably higher. In D.T.D.424 heavy section sand castings may be made with the maximum allowable iron and manganese contents (0·8% and 0·7% respectively) although from the fact that segregation was observed in one alloy with 0·85% iron and only 0·56% manganese it is preferable to keep slightly below these limits, and the limit line in Fig. 2 has been drawn accordingly. Gravity segregation will not be experienced in melts containing the specification maxima provided they are thoroughly stirred after heating to at least 720° C. and that the melt temperature does not fall below 670° C. before pouring.

With L.A.C.112 segregation may occur in heavy section sand castings with the maximum iron and manganese contents (1·0% and 0·5% respectively) and "Fe % + 1·5 Mn %" should preferably not exceed 1·5. Segregation in melts can occur with iron and manganese contents well below those of the specification limits but alloys containing the maximum limits could safely be used for light section castings provided that the melts are heated to at least 700° C. and stirred and subsequently not allowed to fall below 650° C. before pouring.

Trouble may be experienced with the use of these alloys in hot chamber die-casting machines if precautions are not taken. For instance, if D.T.D.424 is to be held at 650° C. the "Fe % + 1·5 Mn %" should not be more than 1·65 and the alloy should first be heated to well above this temperature. If this is not the case, or if the metal temperature is likely to fall below 650° C., the total content of iron and manganese should be further reduced.

In die-casting L.A.C.112, alloys with the specification maxima of iron and manganese can be used at 650° C. provided they are heated to well above this temperature first. With lower temperatures the iron and manganese allowable fall rapidly and if the alloys are likely to be used at just above the "liquidus" temperature, or after adding further solid metal and without reheating to a higher temperature, the safe maximum for "Fe % + 1·5 Mn %" would be under 1.

Comparison of alloys A5 and A6, B5 and B6, and C5 and C6, in Tables I and III, shows that the absence of copper, nickel, magnesium and zinc from alloys A6, B6 and C6 had little effect on the degree of segregation. The normal variations in these elements may therefore be expected to be unimportant in this connection.

Table V summarises the limiting iron and manganese contents of the alloys for use under various conditions. Although high contents of manganese in alloys of the types considered are likely to lead to gravity segregation, it is usually advisable to have a small quantity present. Its effect is to alter the form of iron-bearing constituents to one less harmful to mechanical properties than that which occurs if manganese is absent.

Increasing silicon content appears to lower the temperature at which iron-rich primary crystals begin to separate and thus, in melts held at any particular temperature, to decrease liability to gravity segregation in the melt. On the other hand, silicon additions lower the liquidus temperature of the basis alloy more than they lower the temperature at which iron and manganese separate. Hence at constant superheat, increasing silicon restricts the permissible iron and manganese, as shown in Table IV. The "liquidus" temperatures of

TABLE IV—ALLOYS HELD AT 10°–20° C. ABOVE "APPARENT LIQUIDUS" FOR 45 MINUTES AFTER PRESOLIDIFICATION.

Alloy	Initial composition, %				Analysis of segregate-free positions in quenched ingot, %		
	Si	Fe	Mn	Fe + 1·5 Mn	Fe	Mn	Fe + 1·5 Mn
A	5·4	0·82	0·69	1·85	0·55	0·36	1·09
A2	5·6	0·79	0·42	1·42	0·67	0·28	1·09
B	8·1	1·14	0·52	1·92	0·68	0·21	0·99
C	12·5	1·16	0·52	1·94	0·69	0·23	1·03
C3	12	0·82	0·42	1·45	0·60	0·21	0·91

the alloys were taken as : D.T.D.424, 615° C. ; L.A.C. 112 (low silicon), 600° C. ; L.A.C.112 (high silicon), 580° C., these being the temperatures at which the primary aluminium constituent commences to solidify

* See also Brit. Pat. Spec. 557,553 (1943), "Improved Method of and Apparatus for Refining Metals and Alloys", B.N.F.M.R.A., E. A. G. Liddiard, W. A. Baker and W. H. Glaisher.

in the alloys and not the true liquidus temperatures when the alloys contain sufficient iron and manganese for gravity segregation to occur.

Increase of silicon content lowers the "apparent liquidus," giving longer time in the mould before solidification if the same pouring temperature is used. The consequent heating of the mould causes slower cooling of the melt just above the "liquidus," when gravity segregation is most likely to occur. This effect of high silicon content in promoting gravity segregation is likely to be greater in castings of thick section and may be reduced by lowering the pouring temperature.

Although iron or steel crucibles are attacked by aluminium alloys melted in them, and accordingly have a relatively short life, there was no evidence that the steel tubes used in the experiments described were attacked, and no increase in total iron content of melts was found. Accumulations of iron-rich segregates at the bottom of iron melting pots should not always be ascribed to attack of the pots; they may be due to gravity segregation from the initial melt if the iron and manganese contents exceed the limits now suggested.

Recommendations

In order to ensure uniformity of composition in castings, alloys of the types described should, after melting, be heated to at least 50° C. above the temperature at which segregation would occur on slow cooling, or to a higher temperature if castings are to be made immediately, and should be thoroughly stirred. If further ingots are afterwards added to the melt the same treatment is necessary.

In using alloys of compositions such that gravity segregation is likely to occur in thick section castings, as low a pouring temperature as possible consistent with the proper running of the castings should be used, provided this does not lead to segregation in the crucible.

TABLE V.—LIMITING CONTENTS OF IRON AND MANGANESE RECOMMENDED FOR VARIOUS USES.

USE	D.T.D.424	L.A.C.112
Heavy section castings, melts being kept hot enough to avoid segregation before pouring.	Fe % + 1·5 Mn % = 1·65	Fe % + 1·5 Mn % = 1·5
Melt to be held at 650° C. after heating to well above this temperature.	Fe % + 1·5 Mn % = 1·65	
Melt to be held at 630° C. after heating to well above this temperature.	Fe % + 1·5 Mn % = 1·2	Low Si — Fe + 1·5 Mn % = 1·4
Limits for avoidance of segregation under most severe conditions.	Fe % + 1·5 Mn % = 1·1	Low Si — Fe % + 1·5 Mn % = 0·9 High Si — Fe % + 1·5 Mn % = 0·75

The drilling of ingots or castings often fails to give representative samples for analysis of alloys with high iron and manganese contents. The recommended procedure is to take samples from the molten alloy after heating to 700–750° C. and thoroughly stirring. The sample can be obtained by granulating a small portion of the alloy, or preferably by casting a thin ($\frac{1}{8}$ in.) chill plate. Drillings taken from such a plate provide a satisfactory sample.

In silicon-rich alloys containing iron the presence of a little manganese is desirable provided there is not so much as to lead to segregation.

Acknowledgments

The author is indebted to the Director and Council of The British Non-Ferrous Metals Research Association for permission to publish this paper. Thanks are also due to Dr. H. Moore, who kindly prepared the text for publication.

Royal Visit to Johnson, Matthey's Works

THE platinum smelter and refinery of Johnson, Matthey & Co., Ltd., at Brimsdown, Middlesex, which has recently been considerably extended, was visited on Thursday, February 22nd, by H.R.H. the Duchess of Kent. Her Royal Highness was conducted through the new plant by the Chairman of the company, Mr. H. W. P. Matthey, and saw various stages in the smelting and refining of platinum and of the other metals that comprise the platinum group—palladium, iridium, osmium, ruthenium and rhodium. She also visited the refinery of the company's associate, Johnson & Sons Smelting Works Ltd., where, among other processes employed in the refinery of gold and silver, she saw the treatment of demonetised silver coinage.

The widespread adoption of platinum as an essential industrial metal and its application in the jewellery and kindred trades were demonstrated by a selection of the company's products, which included both samples of metal in the basic material forms of sheet, wire and tubing and examples of partially or wholly manufactured pieces, including laboratory apparatus, catalyst gauzes, electrical contacts and jewellers' findings.

At the conclusion of her tour, the Duchess was presented by Mr. H. W. P. Matthey with a jewelled compact in platinum and 18 carat gold alloy. This, specially designed and produced by Asprey & Co., Ltd., of New Bond Street, was unique in that the platinum used in its manufacture was taken from the very first output of the new refinery, while the gold was refined by Johnson & Sons from the same parcel of Welsh ore from which Her Royal Highness' wedding ring was produced.

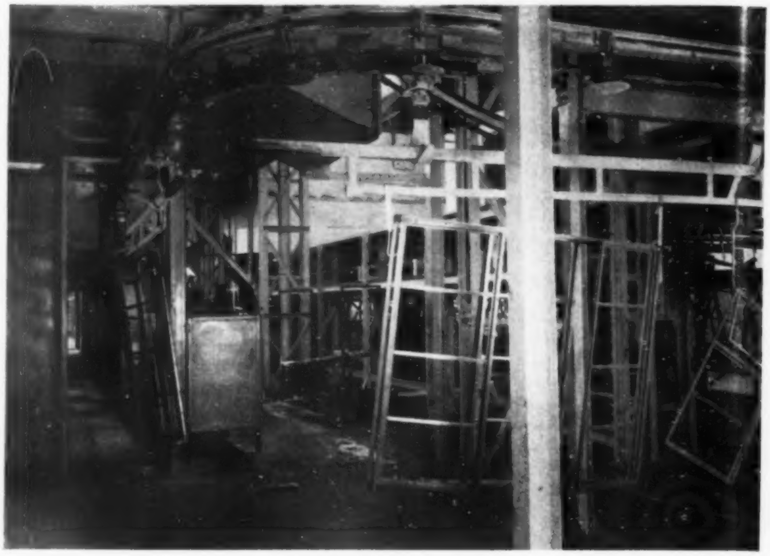
Corrosion Studies and the Engineer

THE British Iron and Steel Research Association announces that Dr. U. R. Evans, F.R.S., of the Department of Metallurgy, Cambridge University, will give a public lecture on "Fundamental Studies of Corrosion and their Importance to the Engineer" on Wednesday, March 28th, at the Institution of Civil Engineers, London, at 5-30 p.m. Mr. T. M. Herbert, Director of Research, The Railway Executive, will be in the chair. Tea will be served from 4-45 p.m.

Dr. Evans will, it is understood, touch on recent important work on corrosion fatigue and its prevention, contact corrosion by dissimilar materials, water-soluble inhibitors, metallic coats and paints with special reference to paint failure by alkaline softening and to some new types of priming. He will bring out some results of practical importance to engineers, which have emerged from scientific investigations on these subjects.

This is something of a new departure, in that the scientist who is investigating the causes of phenomena is addressing himself on this occasion directly to the engineer, in distinction to the more usual occasions when he is speaking to chemists and metallurgists.

Metal Window Finishing Plant



OF great interest from the modern engineering point of view is the special plant at the Hooton Works of Williams & Williams, Ltd., a few miles from their main factory at Chester, for the final treatment and finishing of their metal windows. This plant contains a very large machine fed from the welding shop where the windows, after inspection, are placed on a flight bar suspended from a mono-rail conveyor chain. The windows take 2 hours 38 minutes 30 seconds to travel completely through the machine, and the loading of the conveyor belt is a tricky business which must be worked in conjunction with the factory clock and meal-time schedules to ensure adequate labour at the unloading end

The windows first travel into the first of the four 20 ft. high rows of totally enclosed apparatus contained in a hall 250 ft. long by 150 ft. wide. Two steel arms emerge from the housing and, describing an arc of 90°, raise the flight bar and window from the mono-rail and transfer it to two independent rails running inside the housing. This is an operation requiring perfect synchronisation.

There are 21 separate sets of conveyors in the whole process plant and all have to be synchronised. In the first housing, the metal windows are lowered into two baths of 3% caustic soda, washed in two neutralising baths and passed through the Granodine rust proofing bath, followed by a chromic acid wash and then, travelling at a higher level, into a dry-off oven. Two minutes later the window emerges from the first housing, turns left on to the transverse conveyor and disappears into the second housing. In this the window is given a primer dip and after draining is baked in a second oven at 375° F., after which it is ready for the first process plant inspection.

The conveyor chain now passes through four spray booths, two right side and two left. Due to the efficient air conditioning and high replacement power of the two centrifugal fans, each with 60,000 cu.ft./min. capacity, and each driven by a 30 H.P. motor, the air inside the booths and the whole process area is comparable with that outside the building. All spray not deposited on the window is drawn through a grid in the floor and over jets of water. After each side of the window is sprayed twice the conveyor passes it to the fourth housing, where it is slowly dried in a medium temperature oven some 108 ft. long from which it emerges with a beautifully smooth finish, quite dry and hard but warm to the touch.

Since there is so much paint in proximity to warm air the most up-to-date fire extinguishing system is in use. By the side of each housing are batteries of fire extinguishers containing carbon dioxide gas, each approximately 9 ft. high, and all interconnected with the top interior of the housings. As soon as the temperature at any point at the side of each battery reaches a certain figure, a valve releases the contents of the extinguishers, and the paint tanks evacuate their contents into subterranean dumps ; the gas and power are automatically shut off. If anything happens to the mechanism of the process plant, such as a broken shear pin, tell-tale red lights indicate the position of the breakdown, which would otherwise not be easy to find in a plant of such magnitude.

After leaving the final bake the mono-rail conveys the windows out of the process hall into a large assembly and despatch shop, divided into bays where the unloading men collate the various types of window for packing and despatch. As stated, the whole process for each window takes exactly 2 hours 38 minutes 30 seconds, from the welding shop to the final unloading bay, during which period the window and flight bar are mechanically transferred 42 times. This is a considerable engineering feat, especially in view of the fact that some of the chains are running at a temperature of 375° F. and others running cold, while the permitted variation in stretch throughout the system is less than half an inch.

Production Engineering Research Lecture

AN illustrated lecture entitled "Economic Advantages of Production Engineering Research," showing the considerable economic gains that can be achieved by the co-operation of executives and production personnel in industry with the industrial research organisation, will be given by Dr. D. F. Galloway, Director of Research of the Productive Engineering Research Association, on Wednesday, April 11th, at 7-30 p.m., at the College of Technology and Commerce, Leicester. The Chairman of the meeting will be Col. Sir Robert Martin, C.M.G., T.D., D.L.

The Industrial Economics of Metallurgy

Presidential Address to the Institute of Metals

At the Annual General Meeting of the Institute of Metals which was held in London from March 13–15, Professor A. J. Murphy, Professor of Industrial Metallurgy in the University of Birmingham, took over the duties of President from Mr. H. S. Tasker. In his Presidential Address, Professor Murphy, after dealing with a number of personal and domestic matters concerning the Institute, proceeded to discuss the responsibilities of the Institute to the community at large. A condensed version of this part of the address is presented here.

THIS country has seen a most critical situation arise in recent months in connection with most of the non-ferrous metals of major importance, and trends in other parts of the world are very similar. The supply of copper and zinc in relation to demand has become so precarious that drastic curtailment of releases of the metals has become necessary, and aluminium as an alternative is no longer available: lead is exceedingly difficult to come by, while tin has settled down as a four-figure metal in £s per ton.

In so far as the metallic resources are represented by mineral ores, they are, perhaps, more properly the concern of the Institution of Mining and Metallurgy. Even the most complete knowledge of the reserves of metal in the ground, of rates of production, and of the economics of mining would still, however, leave untouched factors of immense importance affecting the availability of metal for use by the metal-working industry.

An important factor in producing the present shortages has undoubtedly been the precautionary stockpiling which has been adopted as a part of their policy by so many States. If this were the only factor, or the greatly predominant factor, it would be serious enough since the balance of our complex industry is so delicate that even a temporary diversion of raw materials can have devastating consequences for companies and individuals far outside the circle of concerns immediately involved. It might be that a stockpiling programme could be accommodated without grave dislocation, albeit certainly at the cost of much inconvenience, if a term could be set to the period of the stockpiling. It is not the practice, however, for stockpilers to announce the size of the stock which they aim to create, and the activity remains an influence of uncertain intensity and duration.

A study of statistics of production and consumption of the principal non-ferrous metals since the beginning of the century reveals a shifting of the balance between supply and demand which is producing a disequilibrium increasing in an exponential manner. Looking at the long-term trend and thinking of developments in decades rather than years, we see influences of an apparently permanent and potent nature compared with which stockpiling is merely a ripple in a powerful stream. The basic forces spring from three elements: first, the increasing world population; secondly, the essentially exhaustible, non-renewable characteristic of mineral resources; and thirdly, the world demand for high living standards. Imposed on the increase in number of consumers is a steep rise in consumption per head. The effect of a movement towards a higher standard of living has been illustrated by the calculation that if the consumption of copper per head throughout the world rose to be one half of that in the United States, the tonnage of new copper required annually would be 10·9 millions, compared with the present world production of 2·4 million tons.

A situation such as this presents a challenge to all classes of membership of the Institute by posing three questions:

(1) What can we do to improve supplies?
(2) How can we make better use of what we have?
(3) What substitutes can we use in place of the metals which have become difficult in supply?

The Institution of Mining and Metallurgy has long devoted much of its activities to the matters raised by the first question and we may well be content to leave them in their hands, not overlooking our interest in some aspects of refining, such as the thermodynamics of metal-halide reactions, which are rather far removed from process metallurgy as ordinarily understood.

Making better use of what we have means in the first place an examination of the efficiency with which we employ our metals. The use of a higher grade of a metal than the application, or the method of manufacture, technically demands, or the unnecessary use of one metal in place of another more freely available, and likely to remain so, is metallurgically inefficient.

There is another direction in which we must look if we are to secure the most effective outlay of our stores. This involves enquiry into the fate of all the metals which, once having been won from the earth, have survived in the metallic form or as compounds easily reduced once again to metals. These comprise the metals in current service, stock, scrap and the surplus from manufacturing processes such as turnings, clippings and furnace residues. This field of secondary metals has been relatively neglected by scientific metallurgy. A variety of causes has probably been responsible for this neglect. One may well have been the reluctance of metallurgists to study the leavings and contaminated side products of industry and society. Another deterrent has been provided by the complexity of many secondary metals, and the difficulty in deducing the effects of the simultaneous presence in an alloy of several impurities, quite apart from the influence of non-metallic inclusions. Whatever the reasons, it is clear that this indifference cannot persist when we realise how great and vital a part secondary metals play in the economy of the metallurgical industry. In copper, 38% of the metal consumed in 1948 was of secondary origin, in aluminium 30%, in lead 45% and in zinc 28%. It is well-known that the steel industry takes 55% of its metal input as scrap.

In one sense the answer to the third question regarding the use of substitutes is very easily given for any specified application. It calls only for an analysis of the properties

essential to the performance of the service, a reference to the tabulated data for the classes of material offering a prima facie case for consideration, and then a selection in the light of availability. Even within such circumscribed terms of reference, however, the problem may not be simple as, where a usage has existed for a long time, it may be difficult to deduce which characteristics of the metal are indispensable for the application and which are unimportant. Such an approach to the question is only dealing with the first stage in the problem. We must pass from this step to consider the position as regards supplies of the technically acceptable substitute: will they be only temporarily easier and will they be exposed to risks of interruption or curtailment or to fluctuations in price to which the industry has not been accustomed and for which it is not organised? Is the alternative particularly sensitive to contamination, does it involve an unduly large ratio of metal cast to finished product, will it demand troublesome changes in manipulative plant? Only after the patient unravelling of these and similar interwoven threads can the possibility and appropriateness of a substitute be assessed.

My object in making this very brief review of the subject of resources is to discuss what service this Institute can perform in this connection for its members and, indeed, for the community. In the course of our normal activities hitherto we have given little attention to these matters, although our rules do not exclude them explicitly or by implication from our interest, and although they are of the liveliest concern to the great majority of members, in whatever capacity they have to deal with metals. Future readers of our *Journal* for the year 1950 will find no reflection in our papers and discussions of the fact that the non-ferrous metals industry has entered a phase of crisis in its supplies of raw material which is likely to have a profound effect on its immediate fortunes, and its ultimate pattern of development. I feel it is wrong that, as an Institute, we should give this impression of detachment from these problems which are of such vital interest to our members. It may be objected that questions of supply and demand are essentially the affair of the economist and, therefore, not properly brought before our Institute for discussion. But this is a territory in which economic considerations and technical metallurgical factors are most closely linked. For instance, we have the repercussions of the change in practice from cold-rolling to hot-rolling of 70 : 30 brass. While making possible a great acceleration of production this demands a higher grade of purity of metal, and consequently the exclusion of some secondaries which could be used for the cold-rolling process. Such examples could be multiplied by anyone who has to assume a measure of responsibility for policy in a manufacturing concern using or producing semi-finished products of metallurgical industry. A proposal which may be attractive on broad economic grounds may fall down on account of a technical metallurgical obstacle, or a scheme impeccable metallurgically may require for its achievement economic conditions not producible at the time.

I do not doubt there are learned societies and institutions where papers are received dealing with the economic side, but I know of none in which a metallurgist would feel at home in submitting his contributions for joint discussion with the man who would say his own approach was certainly that of the business executive.

My suggestion is that this is a field in which—while most emphatically not contemplating any curtailment of the scientific activity on which its reputation as a learned society has been gained—our Institute can perform a valuable function by providing a forum where these aspects of metal economics can be discussed. I am strongly encouraged to put forward this proposal by a study of the papers which were communicated to the conference, on *Conservation and Utilisation of Resources*, organised by the United Nations Economic and Social Council at Lake Success in 1949. In the sections dealing with metallic resources, there were several papers which would have fallen appropriately within the range I envisage as being covered by this new activity of the Institute.

Such a new activity would conform to the declared aims and objects of the Institute, the two most important of which are: To promote the science and practice of non-ferrous metallurgy in all its branches; and to facilitate the exchange of ideas between members of the Association and the community at large, by holding meetings and by the publication of literature, and in particular by the publication of a Journal dealing with the objects of the Association. If I find any support for the idea, I propose to arrange an informal meeting of members and non-members who might be interested to take part in a discussion of a paper prepared by somebody engaged in this line of enquiry, or even on one or two of the papers to the United Nations conference to which I have already referred. In the event of such a meeting proving successful, not the least of the benefits which the Institute could receive might be some additions to its membership from circles concerned with non-ferrous metals who had not previously found the Institute devoting attention to the aspects of interest to them. But more important than this would be the prospect of making an appreciable contribution to the study, and perhaps the solution, of the gravest problem which has beset non-ferrous metallurgical industry in the lifetime of our Institute.

We may rightly be proud of our past history, with its record of continuous progress; we may take satisfaction from our present membership, which has never been more numerous, and our status which has never been higher. The future of the Institute is in our own hands. If we keep clearly before us the aims and objects which were defined by the founders of the Institute I believe the quality of our work will ensure the material support needed for its continuance, provided we make that work known. If within the affairs of this organisation we are ever watchful for new opportunities of service to metallurgical science and industry, we shall have the satisfaction of finding that in this way we are at the same time discharging our responsibilities to the community and strengthening the growing structure of our Institute.

Conference on the Texture and Structure of Metals

ARRANGED by the X-ray Analysis Group of the Institute of Physics, a Conference on the Texture and Structure of Metals will be held at Ashorne Hill, Leamington Spa, on Thursday and Friday, April 12th and 13th, 1951. A number of interesting papers will be presented and there will be opportunities for discussion. A small exhibition of apparatus, models and diagrams is also being arranged in connection with the Conference.

350-ton Electric Overhead Crane

A CRANE of more than usually high lifting capacity has recently been installed at the works of the English Electric Co., Ltd., at Stafford. The crane was designed and constructed by The Wellman Smith Owen Engineering Corporation, Ltd., of London and Darlaston. It is installed in the new Assembly and Test House and is employed in the handling of heavy power generating sets and particularly hydrogen cooled alternators.

Fig. 1.—View of 350 ton Wellman Crane showing two 175 ton trolleys and snatch blocks (without lifting beam).

The crane is of the double trolley type, each trolley being designed to carry a load of 175 tons. By interlinking the two hoists by means of a cross beam, a total load of 350 tons can be handled. The two trolleys, in addition to the main hoist, each carry an auxiliary hoist of 5 tons lifting capacity, employed for dealing with light loads and, in particular, the heavy slings required for lifting loads on the main hooks.

The crane runs on gantries having centres spaced 77 ft. 9¼ in. apart. Each gantry carries two rails set at 15 in. centres. The height from floor level to rail level is 50 ft. The main hoists are each equipped with 90 h.p. motors running at 700 r.p.m., giving a hoisting speed of 5 f.p.m. The auxiliary hoists have 30 h.p. motors giving a speed of lift of 60 f.p.m. Each trolley is equipped with a 30 h.p. cross traverse motor giving a movement speed of 55 f.p.m. A 120 h.p. motor running at 600 r.p.m. is provided for the long travel motion of the crane giving speeds from 165 down to 115 f.p.m. depending on the weight of load carried. The total weight of the crane with cross beams amounts to 250 tons.

Trolleys. Each hoisting gear consists of cast-iron barrels, two on the main hoist, and one on the auxiliary hoist, driven from a motor through suitable reductions of machine-cut spur gearing. The barrels on each hoist are grooved right and/or left hand and are of sufficient diameter and length to wind the whole of the rope for the full range of lift in a single layer, without overlapping. The rope ends are anchored to the barrels, with additional security being afforded by three extra coils of rope left on the barrel when the hook is in the lowest position. Each hoist motion is fitted with a magnetic brake and lowering of the load is controlled electrically by means of dynamic braking.

The main hoist, auxiliary hoist and cross traverse first and second motion reduction gears are enclosed in welded steel oil bath gearcases with the bearing housings formed integral with the cases. Other gears and exposed rotating parts are provided with sheet steel guards where necessary. The rope sheaves are of large diameter, of cast iron, bushed with gun-metal, and machined and suitably grooved to take the ropes. The pulley pins are arranged for grease gun lubrication.

The traverse cross shaft and barrel shaft bearings are of cast iron, gun-metal bushed and fitted with adjustable caps and provided with nipples for grease gun lubrication. The motor extension shaft bearings are of the roller bearing type. All shafts and axles are of rolled steel, turned and keywayed where necessary, and of ample proportions to withstand all combined torsional and bending stresses to which they are subjected. Flexible couplings of the "Wellman Bibby" all metal type are fitted between all the motors and motor extension shafts. Cast-iron rigid couplings are fitted elsewhere and couplings and wheels secured to their respective shafts by steel keys

The snatch blocks are fitted with gun-metal bushed cast-iron pulleys, suitably guarded to protect them from injury and to prevent the ropes from leaving the grooves. The ramshorn hooks are of forged steel, each carried by a double row ball thrust bearing. Each trolley is mounted on four twin double flanged gun-metal bushed cast steel runner wheels, running on axles fixed in the trolley frame. Two opposite twin runners, one on each side of the frame, are fitted with spur rings, gearing with pinions keyed to the extremities of a cross shaft, the latter being driven from the motor by reductions of spur gear.

Trolley Frames. The trolley frames are of riveted construction, the rolled steel sections being arranged in as simple a manner as possible, to afford ready access to the gearing for cleaning and repairs.

Long Travel Gear. The crane runs on twenty-four wheels, of which six are mounted in each half-end carriage. Four wheels in each half-end carriage are carried in a separate bogie frame pivoted to the carriage structure. As each gantry is supplied with twin rails, the wheels are arranged in pairs, each pair running on the same axle. These twin wheels are of composite construction having rolled steel tyres shrunk on to cast-iron centres, and are double flanged. They are machined on the treads to ensure uniform diameter and are

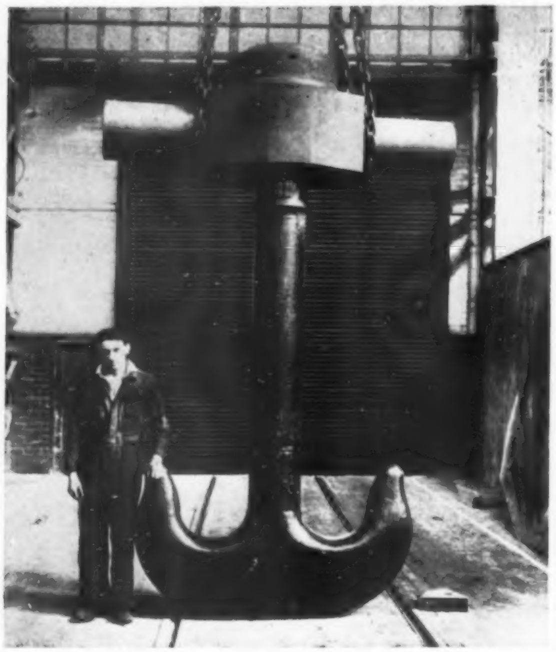


Fig. 2.—350 ton lifting beam hook.

gun-metal bushed to run on centrally lubricated fixed axles. The two independent end carriages at each side of the span are articulated and connected by means of double link plates and pivot pins.

Four twin wheels in two opposite end carriages supporting the same set of girders are fitted with spur rings and are driven from a cross shaft. This cross shaft is carried in gun-metal bushed cast-iron bearings, pitched at close intervals along the girders, and is driven through a reduction of enclosed spur gearing by a motor mounted at approximately the centre of the span to ensure the drive being transmitted simultaneously to both end carriages. This motion is equipped with an electro-hydraulic brake.

Girders and End Carriages. The girders are constructed of two separate units, each of which consists of a main girder of double web plate riveted construction with a lattice braced outrigger girder. The girders of each unit are efficiently braced together in both horizontal and vertical planes to give adequate lateral rigidity and are mounted on box section end carriages. The two units are then linked together to form a compensated whole. On the top flange of each main girder, spaced 7 ft. 9 in. from the crane centre line, are attached twin rails on which the two trolleys run. Timber platforms are arranged on the top level of the girders to give access to the trolleys, and along the bottom level of one girder unit to give access to the long travel gear.

An open type driver's cabin is underslung from one end of the girders enabling the driver to have an unobstructed view of the load in any position. Access to the compartment carrying the electrical control equipment in the girder above being gained from the cabin by means of a steel rung ladder.

The overall dimensions of one main and auxiliary girder are 81 ft. long × 7 ft. 6½ in. deep × 8 ft. 3 in. wide, the weight being approximately 50 tons.

Electrical Equipment. The motors are all of English Electric Co's manufacture, crane pattern, type CAM, totally enclosed, series wound, and half-hour rated for use on a 500 volt direct current supply.

Control on all motions consists of Allen West enclosed contactor panels with unbreakable grid pattern resistances and operated by master controllers of the drum type, the panels being housed in compartments inside the crane girders whilst the resistances are mounted on the platforms above.

All the hoists are arranged for "series" hoisting with "potentiometer" and dynamic "braking" control on the lowering side, whilst the "travel" and both "traverse" motions are arranged for plain series control in either direction. All panels are provided with "series lockout" control so that acceleration is carried out without damage to the motor or control, even if the master controller is improperly handled.

The auxiliary (30 h.p.) hoists and the travel controllers are fitted with crank handles, the "travel" handle incorporating a "deadman" switch. The main (90 h.p.) hoists and the "traverse" controllers have handles specially arranged to enable them to be used independently, or for simultaneous operation when handling the maximum load.

Limit Switches. Each hoist is fitted with a self-resetting limit switch to prevent overhoisting. These are all of the Wellman patent pattern, driven direct from their respective hoist rope barrels, and connected in the control circuit of the main circuit breaker which opens when the limit has been reached.

Brakes. All four hoists are fitted with a series wound Igranic "M" type magnetic brake, of the direct-acting short-stroke pattern, whilst the "travel" motion is fitted with a similar brake but of the "hydro-electric" pattern having a continuously rated shunt coil. This brake is arranged on the motor extension shaft and is connected so that it remains "off" during normal use of the crane, but may be applied at will by the driver, for which purpose a foot-pedal operating a hydraulic master cylinder is provided in the driver's cab. The brake is automatically applied on current failure, by pressing the "emergency stop" push-button or on opening the main isolating switch.

Protection. A crane protective panel of the wall-mounting type is provided and situated in the contactor compartment located in the girders. The panel consists of a main double-pole contactor type circuit breaker and self-resetting overload relays, one for each motor and one common relay on the negative main. These are arranged to open the circuit breaker in the event of overload occurring on any motor, the breaker also opening on failure of voltage, tripping of a limit switch, pressing the "emergency stop" pushbutton, or releasing the "deadman" switch whilst the "travel" motion is being operated. The breaker re-closes only when all controllers are brought to the "off" position.

Main Isolator. A 500 ampere, double-pole, ironclad switch of "English Electric" manufacture is provided to isolate the crane completely from the main downshop conductors. Switch-fuses are also provided for the lighting in the driver's cab, the lighting in the contactor compartments in the girder, and for sockets to feed inspection lamps.

Wiring. Current is conveyed to both trolleys by strained bare wire conductors of high conductivity hard-drawn copper, the trolley picking up from these by means

of sliding collectors of the carbon-insert pattern. The main downshop conductors are of the rigid "T" bar type, the collectors being of the pantagraph pattern.

All the wiring on the crane between the various controllers, panels, and motors is carried out in 660 volt Grade C.M.A., V.I.R. cable, run in enamelled conduit and earthed to the crane structure.

Erection. The end carriages half lengths were lifted on the Track and suitably spaced apart for reception of the main girders. A special 120 ft. derrick capable of lifting 60 tons was employed and this was positioned so that either girder could be raised as required. As each girder was lifted into position, it was bolted to its own end carriage sections the distance between the main girders being such as to allow one of the main trolleys to be lifted between them. One main trolley was assembled complete and then lifted high enough to clear the main girders with the derrick in the same position. The two main girders were closed in to the required centres and the trolley lowered on the track. The second trolley frame was assembled complete without its mechanical gear and lifted end ways through the girders, righted and set down. The mechanical gear was then assembled and the derrick dismantled.

The crane is of substantial construction throughout and special attention has been paid to the ease of accessibility of all parts for inspection and lubrication. It will, if desired, take an overload up to 400 tons.

Correspondence

Cumulative Damage in Fatigue

The Editor, METALLURGIA.

Dear Sir,

I would refer to the valuable review by Mr. Mitchell on "Cumulative Damage in Fatigue" published in your January issue.

In noting that this review is intended as an assessment of a problem which Mr. Mitchell hopes to investigate, it occurs to the subscriber that no mention has been made of "Core Loss" techniques, developed by Cavanagh and Wlodck[1] in North America. The so-called Dyna-magnetic Analyser, described by these investigators provides a means of measuring internal micro-stresses or imposed stress variations in dynamically loaded ferro-magnetic test pieces. Simpler instruments, such as the Cyclograph, may be used, providing they are calibrated against the Dyna-magnetic Analyser.

In the paper referred to above, experimental evidence is presented which shows that the measurement of internal micro-stresses by magnetic analysis methods allows a prediction of eventual failure by fatigue. When the endurance limit was not exceeded, the internal micro-stresses were found to build up in opposition to slip and cold working, until a balance was achieved between the tendency to slip and internal microstress. When the endurance limit was exceeded, magnetic analysis revealed that internal microstresses failed to prevent slip occurring after a few thousand stress cycles, the slip starting fairly slowly, then increasing sharply in rate, then slowing up again before failure.

More recently, Cavanagh, Wlodck, Chalmers and Martius[2] have returned to the potentialities of this technique in the study of deformation and failure, and have described an extensive research programme in progress. It would seem to provide, in part, a rational technique for the prediction of failure, and with further development, may become a more quantitative tool; in cases where under-stressing or over-stressing occurs, there is no apparent objection to its extended use.

It is interesting to note that the same technique has been applied by Moore[3] to the investigation of the correlation between core loss and the transition temperature at which mild steel exhibits the much discussed brittle fracture. This worker's results were reasonably convincing, although their limited scale did not allow fully conclusive claims to be made.

I would suggest that Mr. Mitchell should consider the works referred to, as the techniques might provide a most useful tool in future research in this country.

Yours faithfully,

A. C. RANKIN,
Senior Research Metallurgist.

Kelvin & Hughes (Industrial), Ltd.,
110, Bothwell Street,
Glasgow, C.2. 5th February, 1951.

[1] Magnetic Stress Analysis, P. E. Cavanagh and T. Wlodck, *A.S.T.M. Symposium on Magnetic Testing*, 1948, p. 123.
[2] Internal Microstrain and the Deformation and Failure of Metals. P. E. Cavanagh, T. Wlodck, B. Chalmers and U. Martius, *The Canadian Inst. Mining and Metallurgical Engineers*, Vol. LIII, 1950.
[3] Correlation of Core Loss and Embrittlement of Mild Steel. C. P. Moore, Thesis, Mass. Inst. of Technology, 1948.

The Editor, METALLURGIA.

Dear Sir,

I would refer to the interesting letter from Mr. Rankin concerning my article on "Cumulative Damage in Fatigue" published in your January issue.

No mention was made of the Dyna-magnetic method of testing, primarily because it was not considered relevant to the subject under review; to have included all known methods of fatigue testing in any detail would have made the article unnecessarily lengthy.

The Dyna-magnetic Analyser is, it is agreed, a useful research tool, but it has its limitations, foremost of these being that weakly ferro-magnetic and paramagnetic materials cannot be tested by this method. This, therefore, rules out many important engineering materials, such as aluminium and its associated alloys, the Nimonic series of alloys and many of the high temperature alloys.

My thanks are due to Mr. Rankin for his interest in the article, and I trust that the review will in some small way be of service in his own sphere of activities.

Yours faithfully,

K. W. MITCHELL,
Research Engineer.

Fulmer Research Institute, Ltd.,
Stoke Poges, Bucks. 22nd February, 1951.

Amalgamation of Metallargical Organisations

The Editor, METALLURGIA,

Dear Sir,

In his letter to you in the February issue, Mr. H. S. Tasker refers to my previous letter dealing with the possible amalgamation of the three institutions at present catering for metallurgists. In his analysis of the case for

and against amalgamation, Mr. Tasker details some of the factors which occur to those who have given some thought to the matter and also adduces reasons against amalgamation which would not at once be evident to the ordinary member outside Council circles. In this respect, Mr. Tasker's letter is a real contribution to members who must have all the facts before arriving at a decision.

There are, however, one or two points in Mr. Tasker's letter on which I would like to comment. First of all, however, I should state that there was no doubt in my own mind of the difficulties of the proposed amalgamation. Such an operation could not be undertaken lightly and some of the difficulties to be overcome leap to the mind. If, however, a reasonable case can be made for amalgamation and if the majority of members desire it, then the difficulties must be overcome.

On the matter of subscription rates and their load on younger men, Mr. Tasker does not mention the important changes which have taken place in the age limits for subscription groups. These changes involve some of the younger men in increases of the order of 300%. Whatever may be the justification for the present charges, the fact remains that they are too high. The solution proposed by Mr. Tasker at the end of his letter—to transfer the burden to industry—is one which too many people are trying at the present time, and there is a limit to the burden which industry can bear.

The matter of taxation, based on function, is admittedly a thorny one. Is it quite certain, however, that an organisation providing both qualifying and publication services would have all its income taxed on the basis of its functions as a qualifying body?

As a purely personal opinion, I disagree entirely with Mr. Tasker's view that the two Institutes cater for two distinct types of membership. Such distinction as there is, I suggest, has arisen from the separation of the two publishing Institutes in the past and is to be deplored. A compartmenting of metallurgy into two such groups is, in my view, neither good metallurgy nor good business.

One must, of course, give serious attention to Mr. Tasker's analysis of publication costs and his view that no economies will derive from amalgamation. On the face of it, however, one recognises this problem as one which occurs frequently in business at the present time and the epithet "rationalisation" has been applied to the method of handling it in business.

I must confess I fail to see the basis of Mr. Tasker's claim that advertising revenue would necessarily fall if the combined institutes produced a joint volume.

Finally, I would reiterate that my proposal visualised more than the amalgamation of the two publishing institutes. Any solution excluding the Institution of Metallurgists would not be a complete solution.

Yours faithfully,

F. H. KEATING.

Eaglescliffe, Co. Durham. 15th February, 1951.

Mr. Keating's first letter was published in the January issue, his address being given as "Imperial Chemical Industries, Ltd., Billingham Division, Billingham, Co. Durham." He wishes to make it clear that the views and opinions expressed are entirely personal and are not indicative of any official opinion of the Company with which he is associated.—*Editor.*

Sodium Hydride Descaling Plant for Tubes

WHAT is believed to be the largest sodium hydride tube descaling plant in Europe is now in full operation at Accles and Pollock, Ltd., the Tube Investments subsidiary, at Oldbury, Birmingham, for tube sizes ½ in. bore and larger.

The sodium hydride process of descaling has many advantages over acid pickling. Scale or oxide only is removed, and there is no action on the parent metal, which means a considerable saving when dealing with expensive metals and alloys. The molten caustic, being very fluid, readily covers all surfaces, which ensures that the inside surfaces of the tubes are cleaned as well as the outside surfaces. The process is very rapid, and hydrogen embrittlement is impossible.

Briefly, the process consists of immersing the tubes in a bath of molten caustic soda containing about 2% of sodium for slightly longer than is taken to attain the same temperature as the bath (about 370° C.), then removing the tubes from the bath, quenching in cold water, and finally swilling in hot water.

The action of the sodium hydride is to reduce to fine metal powder the oxides on the surfaces of the tubes which are present in the form of scale, the one exception being chromium oxide, which is reduced to a lower oxide. On quenching in cold water, the steam generated blasts off the loose reduced scale or oxide, leaving the surfaces clean, and the final swill in hot water removes any caustic soda and aids drying.

The process can be applied to all metals except those with low melting points and those which are readily attacked by caustic soda. The plant in operation in the stainless steel tube department at Accles and Pollock consists of a drying and pre-heating stove, a molten salt bath electrically heated by electrodes, and two water tanks, one cold and the other heated. Tubes up to 27 ft. long can be handled, and the salt bath is 4 ft. 6 in. wide, with an effective depth of 4 ft.

The sodium hydride generators consist of welded mild steel boxes, open at the bottom, with a hole at the top through which the sodium is added, and covered by lids. The boxes are immersed in the caustic soda for a depth of 15 in. and project about 8 in. above it. Hydrogen, produced from cracked ammonia, is bubbled through the caustic soda and meets the layer of molten sodium floating on the surface inside the generators. Dry blocks of sodium are fed into the generator boxes at sufficient intervals to maintain a sodium hydride content of 1·8–2%.

The tubes to be descaled are placed in steel carriers which are taken through the operations of drying and pre-heating, descaling, cold water quenching and hot water swilling by an overhead crane, remotely controlled by a driver working behind a glass screen.

The new plant will give Accles and Pollock an increased output of stainless steel tubes, which are used in everything from hypodermic needles to giant chemical plants, from milking machines to beer engines.

SIMON-CARVES, LTD., have acquired the firm of Huntington, Heberlein & Co., Ltd., metallurgical, chemical and mechanical engineers, as a wholly-owned subsidiary company. Huntington, Heberlein & Co., Ltd., retain their name and continue to operate from their registered office at 114, Cromwell Road, London, S.W.7.

NEWS AND ANNOUNCEMENTS

B.S.F.A. Takes Over Steel Foundry Research

An agreement has recently been reached between the British Iron and Steel Research Association and the Research and Development Division of the British Steel Founders' Association whereby the latter becomes responsible for the co-operative research requirements of the steel foundry industry.

Work which has been initiated by B.I.S.R.A. in the steel castings field is to be continued under the auspices of the Research and Development Division of the B.S.F.A., certain facilities and funds having been placed at the disposal of the Division by B.I.S.R.A. so that the combined programme of work now confronting the Division can proceed without interruption.

This new and important step also provides close co-ordination on subjects of common interest between B.I.S.R.A. and the Steel Founders' research organisation, to their mutual advantage.

It is recognised that the Steel Castings Division of B.I.S.R.A. has successfully supervised and greatly extended steel castings research since the Steel Castings Research Committee of the Iron and Steel Institute ceased to operate about five years ago, but that the time has now come for the Steel Foundry Industry to take over and support this work in a manner best suited to its own particular needs.

The Research and Development Division of the B.S.F.A. has recently moved from its temporary address in Collegiate Crescent into more spacious premises at Broomgrove Lodge, Broomgrove Road, Sheffield 10. Broomgrove Lodge is to be the Division's permanent administrative headquarters and the acquisition of these new premises is an important part of the expansion programme of this research organisation.

Pneumoconiosis as an Industrial Disease

Dr. Edith Summerskill, Minister of National Insurance has asked the Industrial Injuries Advisory Council to consider further the question of the method of " prescribing " pneumoconiosis as an industrial disease under the National Insurance (Industrial Injuries) Act, 1946, i.e. how the classes of insured persons eligible for benefit for the disease should be defined.

Pneumoconiosis is at present " prescribed " in relation to insured workers in a number of occupations which are known to give rise to a risk of the disease. These occupations include stone and granite quarrying and masoning, sand blasting, pottery manufacture, metal grinding, steel fettling, coal and certain other forms of mining, coal trimming and slate dressing.

The Council's Industrial Diseases Sub-Committee under the Chairmanship of Sir Wilfrid Garrett, who is also Chairman of the Advisory Council, are now reviewing the present method of prescribing pneumoconiosis. They will consider such possible alternatives as prescribing the disease generally for all insured workers, or by reference to occupations involving exposure to concentrations of specified dusts. The Committee may also reconsider the definition of pneumoconiosis for this purpose. It is at present defined as " fibrosis of the lungs due to silica dust, asbestos dust or other dust, and includes the condition of the lungs known as dust-reticulation."

Persons and bodies interested in the question of the method of prescribing pneumoconiosis are invited to submit written evidence for consideration. Communications should be addressed to the Council's Secretary, Mr. S. E. Waldron, O.B.E., Ministry of National Insurance, 30, Euston Square, N.W.1, as soon as possible, and in any event not later than May 1st, 1951. An explanatory memorandum can be obtained on request.

A.F.S. Film on Gating

Through the courtesy of the American Foundrymen's Society, the Research and Development Division of the British Steel Founders' Association has recently had the loan of an interesting film entitled "A Study of the Principles of Gating." The film records the results of a year's work conducted by the Batelle Memorial Institute, in which a technique employing transparent Perspex moulds and water containing a suspension of fine aluminium powder, was used. By filming the flow of liquid in slow motion, the influence of runner, sprue and ingate design and of pouring method upon both mould gas entrainment and turbulence of flow have been demonstrated in an interesting and convincing manner.

The investigation was sponsored by the Aluminium and Magnesium Division of the American Foundrymen's Society, and the results of further studies employing the same technique have more recently been recorded in a colour film, a description of which appeared in the December 1950 issue of the "American Foundryman."

The Research and Development Division has shown the film within its own organisation in several parts of the country, and it has also been presented by the Institute of British Foundrymen both at their Foundry Foremen's Training Course at Ashborne Hill on March 8th, and at a meeting of their technical sub-committee TS24.

McDonald Furnaces, Ltd.

Increased demand for the products of McDonald Furnaces, Ltd., has necessitated the building of new workshops and offices. Work has commenced on the new site at Dawley Brook, Kingswinford, Staffs. and, for the time being, the administrative staff is being accommodated at the Wolverhampton Offices, 22, Bilston St., Wolverhampton (Tel. Wolverhampton 21574), as from Monday, March 12th. This arrangement is temporary, and further notice will be given when the new offices are occupied.

Advanced Course in Some Recent Advances in Theoretical Metallurgy

A course of about nine lectures, each of which will be followed by a discussion, will be given at the Technical College, Bradford, on Thursdays, at 7 p.m. commencing on Thursday, May 10th, 1951. The lectures will be given by Mr. E. W. Fell, M.Sc., Dr. Ing, F.R.I.C., F.I.M., Senior Assistant in Metallurgy in the College, Mr. W. R. Moore, B.Sc., F.R.I.C., Senior Assistant in Physical Chemistry, and Mr. R. B. Bentley, B.Sc., A.R.I.C., Assistant Lecturer in Physical Chemistry.

The aim of the course is to present some recent advances in theoretical metallurgy, with particular reference to their practical applications. The course is designed particularly for practising metallurgists and advanced students, and will provide an opportunity to keep abreast with modern developments and their practical application.

The following subjects will be specifically dealt with: The atomic and electronic structure of metals; Applications of electronic and atomic theories to the structure and properties of alloys; Some applications of thermodynamics to process metallurgy.

The fee for the Course is £1 5s., and those interested should write to the Principal, Technical College, Bradford, for forms of application, which should be completed and returned as soon as possible.

T.C.M. and Mullard Link

THE directors of The Telegraph Construction and Maintenance Co., Ltd. (Telcon) and Mullard Electronic Products, Ltd., announce the formation of a new company to be known as Telcon Telecommunications, Ltd. The object is to promote and co-ordinate the development, manufacture and sale of Telcon cables and Mullard equipment associated with land line telecommunications. The registered office is at 22, Old Broad Street, London, E.C.2 (headquarters of the Telcon group of companies). The nominal capital of the company is £50,000 and the issued capital will be held by Telcon and Mullard in equal proportions.

The first directors are Mr. J. N. Dean, Mr. J. Innes and Mr. R. C. Mildner, representing Telcon, and Mr. J. P. Jeffcock, Mr. C. L. G. Fairfield and Dr. C. F. Bareford, representing Mullard. Mr. Dean will be Chairman, Mr. Jeffcock, Vice-Chairman, and Mr. Innes, Managing Director.

Personal News

DR. L. B. PFEIL, Director of the Mond Nickel Co., Ltd. and Head of the Company's Research and Development Department has been elected a Fellow of the Royal Society.

MR. J. CROWTHER, formerly Research Metallurgist, has been appointed Chief Metallurgist to Messrs. James Booth & Co., Ltd.

DR. P. K. GLEDHILL has left Messrs. Stewarts and Lloyds, Ltd., to take up an appointment with the British Iron and Steel Research Association, North East Coast Laboratory, Normanby, Middlesbrough.

MR. B. N. H. THORNELY has left the Northern Aluminium Company, Rogerstone, to become Director of Operations with Aluminium, Ltd., Montreal, Canada.

AT a meeting of the Directors of The International Nickel Company of Canada Limited, on March 6th, MR. R. L. PRAIN, O.B.E., London, was appointed to the Board. Mr. Prain who is well known in mining circles in the City is Chairman, Rhodesian Selection Trust, Ltd.; Chairman and Managing Director, Roan Antelope Copper Mines, Ltd.; Chairman and Managing Director, Mufulira Copper Mines, Ltd.; Chairman, Anglo Metal Co., Ltd.; Director, Climax Molybdenum Company of Europe, Ltd., in addition to holding Directorships of several other companies mainly connected with mining.

AT the Annual General Meeting, the President of the E.T.S., Mr. A. W. Wallbank, announced that the Council had conferred the distinction of Honorary Membership on DR. WILLIAM BLUM. Dr. Blum has been associated for very many years with the Bureau of Standards, Washington, and his researches in electrodeposition have contributed greatly to progress in this field.

MR. DONALD MORRIS, B.Com., F.C.W.A., has been appointed Secretary to General Refractories, Ltd., in succession to the late Mr. James Walker, F.A.C.C.A. Mr. Morris has been with the Company for fourteen years and formerly occupied the position of Cost Accountant.

NEWMAN INDUSTRIES, LTD., announce the appointment of MR. E. R. A. MILNE, A.M.I.E.E., who was formerly an Assistant Sales Engineer in the Manchester area, to be Branch Manager for Scotland at their Glasgow Office, in charge of Electric Motor Sales.

THE Council of the Institute of Marine Engineers have appointed to succeed Mr. B. C. Curling, who will retire from the Secretaryship of the Institute in October next, MR. J. STUART ROBINSON, M.A.(Cantab.), who has been Assistant Secretary of the Institute for the past three years. Mr. Robinson, who is 30, was educated at Repton School and Jesus College, Cambridge.

THE Directors of The Anglo Metal Co., Ltd., announce the appointment of MR. L. K. BRINDLEY, M.B.E., to the Board with effect as of March 9th, 1951.

DR. JOHN F. THOMPSON, President of The International Nickel Company of Canada, Ltd., was elected Chairman of the Board of Directors, succeeding the late Robert C. Stanley, at a special meeting of the Board on February 28th, 1951. He continues as President, which office he has held since February 7th, 1949. DR. PAUL D. MERICA, Executive Vice-President and a Director, was elected a member of both the Executive Committee and Advisory Committee of the Company.

THE Council of the Royal Aeronautical Society, at their meeting of February 22nd, 1951, appointed DR. ARCHIBALD MORTON BALLANTYNE, Associate Fellow, to succeed Captain J. Laurence Pritchard as Secretary of the Society. Dr. Ballantyne (who is 42 years of age) is the Senior Lecturer in the Civil and Municipal Engineering Department of University College, London. Dr. Ballantyne will take over his duties as Secretary on Monday, July 2nd, 1951.

MR. JOHN PALMER, who recently celebrated his 25 years' service with the Mullard organisation, officially retired on January 31st. Mr. Palmer was an outstanding personality, and was held in high esteem by people in the Mullard distributing organisation in every continent of the world. Mr. Palmer was engaged in export business during the greater part of his career, and his knowledge of international trade was encyclopædic. Before the war he was actively concerned with all Mullard interests abroad, but as a result of post-war expansion of Mullard export business, he subsequently specialised on valves and electron tubes only. With the formation, on May 1st, 1950, of Mullard Overseas Limited, Mr. Palmer took over complete control of the Company's valve interests abroad.

MR. RODNEY KENT, Sales Director of George Kent, Ltd., London and Luton, sailed for Australia on March 1st, accompanied by Mrs. Kent. He is making an extensive

tour of George Kent branches and agents in Australia and New Zealand. This tour of Australia will last six weeks and on May 15th, Mr. and Mrs. Kent will travel by air to New Zealand and spend two weeks there, Mrs. Kent afterwards returning to England by sea. Mr. Kent, after a further month in Australia, will return to England by air via America, where he will spend some days.

British Standards Institution

Golden Jubilee Exhibition

This year the British Standards movement attains its Golden Jubilee, and as a part of the celebrations an Exhibition, supported by practically the whole range of British Industry, will be held at the Science Museum, South Kensington, during the two weeks beginning June 18th, 1951. As Britain was the first country to put industrial standardization on an organised basis nationally through the British Standards Institution, it is fitting that the first exhibition devoted to this subject should be staged in London—and during the national Festival year.

The benefits derived from standards, standardisation and simplification will be graphically presented, and each industry will show how standards have simplified production, reduced costs and maintained quality, and how in turn they have benefited the users of that industry's products. The Exhibition will also show how research at one end of the production chain and quality control at the other are linked with and helped by standardisation. Other special features will include apparatus used in testing for compliance with British Standards.

The Exhibition will be opened at 11-30 a.m. on June 18th by the President of the Board of Trade. Admission will be free, and opening hours will be 10 a.m. to 7 p.m. each day (except Sunday), from June 18th to 28th, inclusive.

New and Revised Standards

Electroplated Coatings of Nickel and Chromium on Steel and Brass. (B.S.1224 : 1945)

In view of the shortage of nickel which has developed recently, a special meeting of Committees of the British Standards Institution concerned with the preparation of Standards relating to electroplated coatings of nickel, was held in order to determine what steps should be taken. The meeting was unanimously of the opinion that B.S.1224, Electroplated coatings of nickel and chromium on steel and brass, the only Standard at present published in relation to such coatings, should not be amended, but that a memorandum should be issued drawing attention to the provisions of the standard, which enable the amount of nickel used to be reduced. This memorandum has now been published, and will be inserted in all copies of B.S.1224 sold.

For the benefit of those who have already a copy of B.S.1224 in their possession, we repeat the wording of the memorandum as follows :—

In view of the present shortage of supplies of nickel, and the importance of making the most efficient use of the supplies available, attention is drawn to the definition of the significant surface for plating on page 5 of this British Standard, which enables the manufacturer, by agreement with the purchaser, to reduce the surface to be coated in accordance with the standard.

Attention is also drawn to the Note, on page 7, relating to standard classifications :

Ni 8S and Ni 5S

according to which the minimum deposit thickness may be a composite deposit of nickel and copper, provided that the final deposit of nickel is at least 50% of the whole.

Forged Steel Socket-Welding Fittings for the Petroleum Industry. (B.S.1684 : 1950)

A further British Standard has just been issued in the series which is being prepared for equipment for the petroleum industry, viz. B.S. 1684, Forged steel socket-welding fittings for the petroleum industry. This document is based on two American specifications, ASA. B16.11 and A.S.T.M. A234. It gives details of the sizes, materials, body thicknesses, tolerances, tests and marking, together with tables giving the full details of all the necessary dimensions required for socket-welding, elbows, tees, crosses, 45° elbows, couplings and caps.

Determination of Titanium in Permanent Magnet Alloys, Part 17

Determination of Chromium in Ferro-Chromium, Part 18.

(B.S. 1121 : 1951, Parts 17 and 18).

Two methods are specified for the determination of titanium. Using the gravimetric finish, titanium is precipitated with cupferron from a solution of the alloy containing the iron in the ferrous condition. After ignition and fusion, iron, copper and traces of nickel, cobalt, etc., are removed from an alkaline tartrate solution with hydrogen sulphide. Finally titanium is again precipitated with cupferron, ignited to oxide and weighed. Using the absorptiometric finish, hydrogen peroxide is added to an oxidized solution of the alloy in a mixture of sulphuric and phosphoric acids. The light absorption of the yellow coloured pertitanic acid thus produced is measured and related to a calibration curve prepared under the same conditions as the assay.

The method for determining chromium in ferro-chromium is by decomposition of the alloy by digestion with sulphuric acid, fuming with phosphoric acid, oxidation with silver nitrate/ammonium persulphate and titration with ferrous ammonium sulphate and standard dichromate using diphenylamine as an indicator.

Aluminium and Aluminium Alloy Sections (Revision of B.S. 1161 : 1951).

This Standard, which was first published in 1944, has now been extended to cover additional sizes of aluminium alloy sections and to include sections made for incorporation in designs, and most manufacturers are in a position to supply almost the full range. It may, however, be some time before some of the manufacturers can supply all sizes. Many suppliers are able to make larger sections than those given in the table, but it is not yet practicable to standardise these. The sections covered in the new edition are as follows :—

Equal angle sections ..	¾ in. × ¾ in. to 9 in. × 9 in.
Unequal angle sections	1½ in. × 1 in. to 12 in. × 6 in.
Channel sections ..	3 in. × 1½ in. to 12 in. × 4 in.
I sections	3 in. × 1½ in. to 12 in. × 6 in.
Tee sections	1 in. × 1 in. to 9 in. × 9 in.

Copies of the above Standards may be obtained from the British Standards Institution, Sales Department, 24, Victoria Street, London, S.W.1. The prices are as follows :—B.S. 1224, 3s. ; B.S. 1684, 3s. ; B.S. 1121 (Part 17), 2s. ; B.S. 1121 (Part 18), 1s. ; and B.S. 1161, 5s.

CURRENT LITERATURE

Book Review

CONDUCTIMETRIC ANALYSIS AT RADIO-FREQUENCY

By G. G. Blake. Pp. xv + 109. Chapman and Hall Ltd., London. 1950. 15s. net.

THIS is a book by a physicist which is of considerable value to the chemist. It describes the application of radio-frequency oscillations to the study of solutions, in particular, of titration processes. Using cylindrical electrodes which are place *around* the tube into which the solution is drawn and *not* in the solution itself, troubles due to polarisation, surface-adsorption, etc., do not occur. The method is sensitive and may be used to match the concentrations of solutions. Not only may simple titrations be performed on both ordinary and micro scales, but really tricky problems, such as the rapid micro-determination of the rates of diffusion of dissolved electrolytes, may be tackled. The application of the technique to numerous problems in widely-varying branches of science is also suggested. All chemists will be interested in the simple " dipper units " used by the author as alternatives to micro-pipettes in small-scale analysis. (An account of these units appeared in METALLURGIA, May, 1950.)

A long appendix follows the nine chapters of the book, which is subdivided into 114 numbered sections. This subdivision, together with really useful indexing and bibliography, makes for easy reference. Printing, illustrations and general production are very good. No errors were detected, except that on comparing the diagram of the diffusiometer with the description given on page 23, it would appear that brass strip Y should be 20 (not 2) mm. long.

In his conclusion, the author refers to the gradual development of his work and indicates that some of this has taken place during the passage of the book through the press. This is the spirit of the whole work, which is an admirable example of the stepwise development of a good basic idea. Rightly or wrongly, it has been said that physicists may be divided into two groups, the practising and the theoretical. On this basis, Mr. Blake obviously belongs to the former group. It is clear from his writings that not only has he designed the apparatus he describes, but has repeatedly used it. The host of little practical tips included suggest that he is not above making the apparatus himself. Consequently, his descriptions are straightforward and to the point. Explanations of the fundamentals involved are in the simplest terms and must have been the subject of much thought. We are therefore, spared the mathematical smoke-screen which might have formed the " explanation " of a less painstaking author.

That an appendix is frequently to be consulted but rarely to be read does not apply here. Far from being a collection of tables, the appendix of this book is filled with interesting ideas. Mr. Blake's experience in the field of telecommunications goes back to the early days and he has seen the growth of electronics into a major branch of science. He is thus easily able to resist burying the essential simplicity of the technique in an over-enthusiastic welter of complex electronic hook-ups. Instead, the reader is presented with simple circuits and some practical points of design. To do a job well is often to do it simply!

If Mr. Blake would now produce another book on these highly practical lines, dealing with electronics as generally applicable in chemistry, he would add to the service he has already rendered in preparing the present volume.

J. T. STOCK.

Books Received

" Chemical Analysis of Cast Iron and Foundry Materials," by W. Westwood and A. Mayer (B.C.I.R.A.), 565 pp., 32 illustrations, 12 appendices. George Allen & Unwin, Ltd., London, 1951. 42s. net.

" Gas Producers and Blast Furnaces," by W. ~~Gumz~~ Gumz 316 pp., 66 illustrations, 8 tables. John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., London, 1951. 56s. net.

" Metallurgical Thermochemistry," by O. Kubaschewski and E. Ll. Evans, 368 pp., 103 illustrations, extensive bibliography. Butterworth-Springer, Ltd., London, 1951. 35s. (by post 36s.).

" Iron and Steel Directory and Handbook—1950." Sixth edition. D. 8vo, 302 pp. The Louis Cassier Co., Ltd., London. 25s. (postage 8d.).

Trade Publications

THE manufacture of Tinned and Leadcoated Sheets is the subject of a new brochure just published by Shimwell and Co. Ltd., of Leyton. A number of pages are devoted to a description of the manufacture of " London " Brand Tinned and Leadcoated Sheets, copiously illustrated with photographs of the various operations in progress in the works at Leyton. A variety of products made from " London " Brand sheets are also illustrated, ranging from a large tea-drying installation to a small electric capacitor or condensor. Several pages are devoted to full information on the various grades of tinned sheets, leadcoated sheets and terne-plates; with data and tables of practical importance to purchasing departments, works managers, and estimators.

The firm was established in 1875, and the publication of this brochure marks three quarters of a century of progress in the manufacture of products which to-day are known for their high quality all over the world. A brief history of the growth of the firm completes a highly informative publication, which will be sent on request to Shimwell and Co. Ltd., Wellington Road, Leyton, London, E.10, England.

AN interesting leaflet on Compo Oil-Retaining Bearings, entitled " A Triumph of Powder Metallurgy " is available from Bound Brook Bearings (G.B.), Ltd., Trent Valley Trading Estate, Lichfield, Staffs. In the form of questions and answers, comprehensive information is presented on the uses, properties and economics of these porous bronze bearings.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

"Staffa" Grinding Machines

THE new pedestal mounted grinding machines now being placed on the market by Chamberlain Industries, Ltd., are especially designed to ensure rapid metal removal and the utmost economy from the grinding wheels. Designed in accordance with Home Office regulations, they are suitable for a wide variety of work.

In each of the three models, the symmetrically designed, totally-enclosed type body is fabricated entirely from mild steel plate, with the addition of bracing, where necessary, to eliminate vibration. Ventilating louvres are provided in the side of the casing to allow dissipation of heat from the motor.

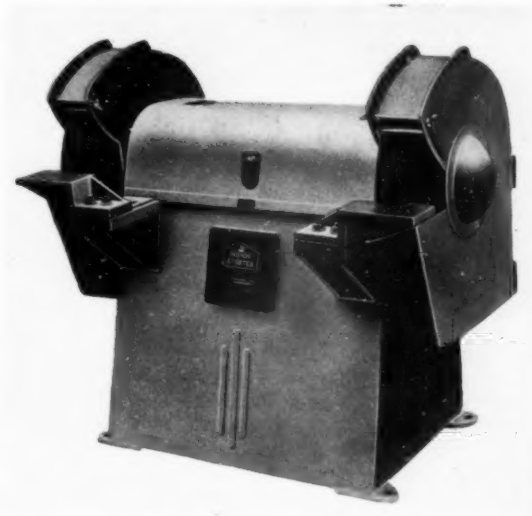
The spindle, which runs in double-row self-aligning ball bearings, is of 35–45 ton bright carbon steel (45–50 ton in the 24 in. × 3 in. machine). Nipples are provided for grease-gun lubrication and a "Tecalemit" greasing system is provided, bearings being lubricated by means of a high pressure feed. Efficient grease seals and dust covers provide adequate protection against dust and abrasive grit. The drive to the spindle from the motor consists of endless rubber vee belts running in grooved pulleys.

Direct-on-line push-button-operated starter switches are provided in compliance with Home Office Regulations and with the general requirements of B.S.S.587. These starters have automatic push-button control with no inherent voltage release. The overload trips are of the thermal type, consisting of bimetal strips, and have the advantage that the full thermal capacity of the motor can be utilised as they do not trip on overloads of short duration which are insufficient to damage the motor.

Exhaust hoods are of heavy gauge steel plate, with adjustable spark arresting flaps to compensate for wheel wear on the diameter, complying with Home Office requirements. Hinged side plates allow for easy changing of grinding wheels, and the removal of accumulated heavy swarf. These side plates are provided with domed caps to enclose the spindle and nuts. Suitable snouts are provided at the back of the guards for coupling up to any exhaust system.

Work rests are provided with horizontal adjustment to allow for wear of wheel diameter, thus avoiding a gap between wheel and rest which might prove dangerous to the operator. An additional advantage of all three models is provided by the reserve power of the motor and the manner in which the wheels are spaced, enabling two operators to work simultaneously in comfort.

The three models are designated 10 in. × 1 in., 16 in. × 2 in., and 24 in. × 3 in., indicating the size of wheel for which they are designed. In the 24 in. × 3 in. model, maximum efficiency is ensured by having three independent speeds provided for each wheel by means of coned pulleys, thus allowing for unequal wear on the two wheels. Accidental over-speeding is prevented by a safety device controlled entirely by the diameter of the wheel. Keyed to the spindle is a grooved collar, and running in the groove in the shape of a yoke are phosphor-bronze bearing pads, specially selected to resist wear. Connected to the fork linkage are the safety rods which



The 24 in. × 3 in. model.

protrude through the sides of the wheel guards in such a manner that if the belts are on the highest speed a new wheel cannot be fitted. The speed cannot be increased unless the wheels have worn down to the correct diameter, enabling the safety rods to move to the next position without contacting the wheels.

Chamberlain Industries, Ltd., Staffa Road, Leyton, London, E.10.

Diesel-Electric Locomotives for Steelworks Use

Two four-wheeled diesel-electric locomotives have recently been designed and built by the Yorkshire Engine Co., Ltd., to meet the requirements of steelworks and other heavy industrial users who require a locomotive of high starting tractive effort and good low-speed performance which will successfully negotiate the severe curves likely to be encountered in the track lay-out.

The starting tractive effort is 24,000 lb. and the weight has been increased by the incorporation of heavy iron and steel castings in the structure. Special buffing gear is fitted to enable the locomotive to withstand the end shocks to which it may be subjected. This type of locomotive is, therefore, very suitable for heavy industrial duties within the loads and speeds for which it is designed, but weight can be reduced, with or without proportionate reduction of tractive effort, for special conditions.

The locomotive is of the rigid-frame type with two axles having 3 ft. 6 in. diameter wheels, coupled together to take care of weight transfer and slip. The inside journal axleboxes have renewable leaded-phosphor-bronze liners, and the laminated springs are overhung, whilst the hornblocks which incorporate the guides for

the spring pillars are fitted with renewable manganese steel liners. Specially designed for rapid and positive action, the clasp brake system is fully compensated and operates on all wheels with an independent cylinder for each. Friction and lost motion is this reduced to a minimum.

The prime mover is a Davey, Paxman Mark 6–RPHL Series I in-line six-cylinder engine, developing 230 B.H.P. at 1,250 r.p.m., solidly coupled to a B.T.H. D.C. generator of the three-winding self-ventilated type R.T.B. 8836 and exciter type DY 1514. Each pair of wheels is driven by a B.T.H. reversible series-wound self-ventilated KE 10-T traction motor through a double reduction gear of 19·75 :1. The motors, which are of the spring-loaded nose-suspension type, are placed longitudinally between the main frames and are hung outwardly on the axles through the gear-box ends, self ventilation being effected through air intakes fitted with Vokes Air filters.

The locomotive is driven by means of a single lever which controls, through mechanical linkage, the engine speed; the initial movement of this lever excites the generator, and further movement increases the engine speed by infinite variation to a maximum, after which it permits field-weakening of the traction motors to be effected under relay control. Reversal is effected by means of a pneumatically operated reverser. A pressure switch connected to the brake system prevents movement of the locomotive without sufficient brake pressure. Adequate mechanical and electrical interlocking between the various controls is provided to prevent incorrect operation.

Yorkshire Engine Co., Ltd., Meadow Hall Works, Sheffield, 9.

Automatic Spot-Welding Machine

Standard Resistance Welders, Ltd., have added to their range of automatic air-operated electric spot-welding machines an 80 and 100 kVA type. The main frame is a very rigid and heavy construction of fabricated steel, all welded, and is such that deflection is eliminated when the heads are at maximum pressure.

The machine was supplied for multiple cross joint welding of wires. The platen electrodes are fitted to water-cooled copper castings, designed to give even distribution of the welding current throughout the whole length of the electrodes, thus ensuring even welding on the full width of the work. It can be fitted with standard renewable water-cooled electrode tips, which are made, taper, to B.S.807. Suitable heads can also be supplied for projection welding. The electrodes are carried in bronze heads which are arranged to permit of both lateral and vertical adjustment.

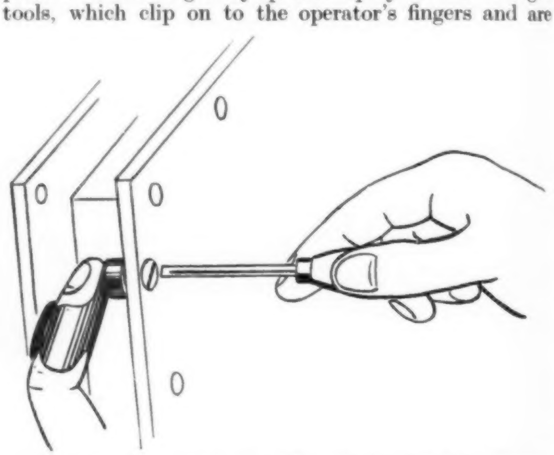
The operating air cylinder is of the double acting type, with the top and underside independently controlled. Independent control is achieved by means of reducing valves, and pressure switches, enabling any pre-set pressure to be obtained, thus the electrodes can be brought on to the work with a light pressure. This pressure cycle being controllable, the weld time is initiated during the period of light pressure, the heavy forge pressure following to complete the welding. When on test, a speed of 70 strokes per min. was obtained, and this is considered to be the maximum for the double pressure principle which, though not so rapid as the single pressure heavy-blow type, has several advantages, amongst which are spot welding perfection, greater welding capacity, longer electrode life due to elimination of heavy blow, and, in the case of projection welding the fact that no collapse occurs before the commencement of the weld.

The machine illustrated can be supplied with " weld, forge and off " control, or to give repeat spotting. This is obtained by keeping the foot switch in the depressed position, and with the addition of a switch, single or repeat spotting can be obtained at will. A heavy-duty rotary switch box controls the full range of the machine.

Standard Resistance Welders, Ltd., Mucklow Hill, Halesowen, Nr. Birmingham.

"Acru" Finger Tools

In the assembly of small parts, there is often a considerable waste of time in picking up various tools. Assembly production can be greatly speeded up by the use of finger tools, which clip on to the operator's fingers and are



available as box tools to hold nuts in position, screwdriver ends to hold screws in position, and tweezers. It is possible to fix as many as four different finger tools on the hand and still work normally.

The Acru Electric Tool Manufacturing Co. Ltd., 123, *Hyde Road, Ardwick, Manchester*, 12.

"Sifbronze" Gas Pressure Regulator

Recently developed in connection with Suffolk Iron Foundry's oxy-acetylene activities, the "Sifbronze" Regulator is now in production. Special features include a single pin self-locating main valve into which is embedded a special composition seating to give reliable valve action and prevent pressure creep. A gauze and pad type filter at the base of the inlet tube prevents rust, dust or dirt getting in to affect the efficient working of the valve, and a compact safety valve operates promptly in case of a sudden pressure rise. The extra-large expansion chamber permits regular and uniform diaphragm movement, thus ensuring a constant delivery pressure when welding or cutting. The gauges are calibrated in white lettering on a coloured background, green for oxygen, and red for acetylene. They can also be used for other gases, including propane and hydrogen. All parts are interchangeable and the neatness of design and bronze-matt finish give the regulator a pleasing appearance.

Suffolk Iron Foundry (1920) *Ltd., Sifbronze Works, Stowmarket.*

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
MARCH, 1951 Vol. XLIII, No. 257

Polarographic Determination of Cadmium in Aluminium Alloys*

By William Stross, M.D., F.R.I.C.
International Alloys, Ltd. Haydon Hill, Aylesbury.

A method for determining cadmium in aluminium alloys is described. The sample is dissolved by attacking with sodium hydroxide, followed by addition of nitric acid. Copper, lead and certain other metals are electrodeposited in presence of ammonium sulphate, the cadmium remaining in solution. The iron is reduced by hydroxylamine at pH3. *Gelatine is added, oxygen is expelled and the cadmium is determined polarographically. None of the usual constituents of aluminium alloys interfere, nor do most of those elements more rarely present. The method has been applied to cadmium contents ranging from 0·01 to 5%, but the range can probably be extended in either direction.*

ALTHOUGH cadmium is a constituent of certain aluminium alloys,[1] the methods published for its determination in such alloys[2,3] are neither particularly rapid nor simple. An attempt was made, therefore, to determine the element polarographically,[4] as it is one of the metals considered most suitable for this method of analysis.[5]

The elements from which interference was to be expected (unless present in substantially smaller quantities than cadmium) were copper, ferric iron, lead and bivalent tin, as their waves precede that of cadmium in the usual media. In a thiocyanate medium (which, together with hydroxylamine, would prevent interference by copper, iron and tin)[6,7] nickel would also interfere as, in this medium, the waves of nickel and cadmium coalesce.[4]

Attempts to deposit the copper and reduce the iron to the non-interfering ferrous form, by adding metallic zinc or aluminium to acid solutions, were abandoned because much cadmium was deposited with the copper.

It was, therefore, decided to resort to preliminary deposition of copper and lead by electrolysis in dilute nitric acid,[8] from which cadmium is not deposited. When the electrolysis is completed, the *p*H is adjusted to 3 (approximately) and the iron is reduced by hydroxylamine. This reduction proceeds smoothly, even at room temperature, to a degree which is practically sufficient, up to an iron content of at least 10%, a limit hardly likely to be exceeded in aluminium alloys, including "hardeners." To be on the safe side, the solutions were heated in a boiling water bath.

Thus, the following procedure was evolved.

The Method

Solutions Required

All reagents should be of "Analytical reagent" grade.

(1) *Sodium hydroxide solution.* Add 1 litre of water to 400 g. of the solid, and dissolve. This solution is approximately 9·3 N.

(2) *Dilute nitric acid* (1 : 1). Add to concentrated nitric acid (sp.gr. 1·42) an equal volume of distilled water.

(3) 50% (*w/v*) *ammonium sulphate solution.* Dissolve 500 g. of the solid in water and make up to 1 litre.

(4) 8*M solution of hydroxylamine hydrochloride.* Dissolve 55·6 g. of the reagent in water and dilute to 100 ml.

(5) 20% (*w/v*) *solution of sodium carbonate.* Dissolve 100 g. of Na_2CO_3 (anh.) in warm water, and dilute to 500 ml.

(6) *Thymol blue* (*Phenolsulphonphthalein*) *indicator.* Triturate 100 mg. of the solid with 2·15 ml. of 0·1 N NaOH and a few ml. of water and make up to 100 ml. with water. After about one day and repeated shaking, filter.

(7) *Gelatine solution,* 0·25%, *kept sterile by Thymol.* Dissolve 0·5 g. in about 100 ml. of hot water, dilute, whilst cooling rapidly, to 200 ml., add a few pea sized Thymol crystals and shake repeatedly during the first hours, in order to reach rapidly a concentration sufficient to suppress microbial growth. Do not add the Thymol whilst the solution is warm, otherwise the solution may become, and remain, milky.

Procedure

Place 2 g. of the accurately weighed sample in a 250 ml. tall beaker and add 4 ml. of the sodium hydroxide solution. Cover with a watchglass and place in a cold water bath (tap water). When the violent reaction has subsided, add another 16 ml. of the same solution, cover and cool again.

In the case of powder, or very fine turnings, it may be

* This article is an abbreviated version of the author's contribution to a collection of papers to be published in Prague in celebration of the 60th birthday (Dec. 20, 1950) of the inventor of polarography, Professor J. Heyrovsky. Readers of Metallurgia who might be interested, may not have easy access to this publication, and the author is very grateful to the Committee arranging Heyrovsky's birthday celebration for permission to publish the essential parts of the MS in METALLURGIA.

1 *e.g.* Specifications D.T.D.294 or B.S.1490–LM–19, also the commercial alloy "Arral A". Re occasional occurrence of cadmium in scrap metal see Stross, W., *Analyst*, 1949, **74**, 288.
2 "Chemical Analysis of Aluminium and its Alloys," The British Aluminium Co., Ltd., Publication No. 405, 1947, p. 57.
3 "Chemical Analysis of Aluminum," Aluminum Co. of America, 1950, p. 36.
4 For the polarographic determination of cadmium in magnesium based alloys see Stross, W., *Analyst*, 1949, **74**, 288.
5 See *e.g.* Stackelberg M.v., "Polarographische Arbeitsmethoden," W. de Gruyter & Co., Berlin, W. 35, 1950, p. 127.
6 Kolthoff, I. M. and Matsuyama, G., Ind. Eng. Chem. (Anal. Ed.), 1945, **17**, 61
7 Stross, W., *Metallurgia*, 1947, **37**, 49 and 1950, **41**, 284.
8 Osborn, G. H., *Metallurgia*, 1949, **40**, 111.

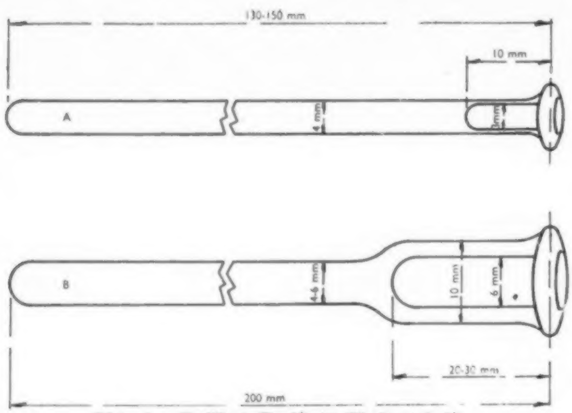


Fig. 1.—Boiling Rod* (" Siedestab ")

* Sketch A shows the rods used by Dr. Cohen, who kindly supplied full details. Sketch B shows the rods, used by the author and supplied in Pyrex glass by Messrs. C. A. Hendley & Co., Green Walk, Woodford Bridge, Essex. He feels that they facilitate the recovery of liquid or solid adhering to the interior of the " bell." For the same reason, any constrictions of this part, particularly of the opening, should be avoided, and the top of the bell (or U-shaped part) should be as flat as possible. The dimensions are not critical.

necessary to add the sodium hydroxide solution in smaller portions (e.g. 2·5 + 2·5 + 15 ml.).

When the reaction calms down, wash down the walls with a little water, using a glass rod to detach any particles adhering to the wall. Boil to complete the reaction; boil down to low bulk if the silicon content is greater than about 4%.

Dilute to about 50 ml. and cautiously add, with vigorous stirring, 60 ml. of the diluted nitric acid. Stir thoroughly, cover with a watchglass and boil for a short time to dissolve the precipitated aluminium hydroxide and to drive off nitrous fumes.

During this part of the operation there is some tendency to bumping and the " boiling rods " described by Cohen[9] are useful although not essential. The writer found these rods generally very useful, as they not only ensure smooth boiling but serve as normal glass rods (stirrers) as well; thinking that the readers of this journal might be interested, he asked for the author's and publisher's permission—which the writer herewith gratefully acknowledges—to reproduce their illustration of the boiling rod, called " Siedestab " by Cohen, Fig. 1.

Cool, add 10 ml. of the ammonium sulphate solution (which seems to promote the completeness of the deposition of the copper and to improve the appearance of the deposit) and electrolyse.

The writer uses stationary cylindrical platinum gauze electrodes[10] and stirs vigorously by motor. 1 hour at 5 amp. leads to satisfactory deposition of copper and lead, leaving in the electrolyte not more than a few hundredths of 1% of copper and lead, but often considerably less than 0·01% of copper (as determined by the sodium diethyl-dithio-carbamate technique)[11] even with alloys containing 10% of copper and 2% of lead. If the electrodes are weighed before and after the electrolysis, copper and lead can also be determined with very little extra work.

9 Cohen, A., " Rationelle Metallanalyse." Publisher, Birkhaeuser, Basle, 1948, p. 61.

10 The cathodes are approximately 45 mm. high and 45 mm. in diameter, the anodes about 30 mm. high and 34 mm. in diameter; the surfaces are, according to the makers, about 130 and 170 sq. cm. respectively. With suitably smaller electrodes, it should be possible to work in such a small volume that one could start with a 200 mg. sample; this would further simplify the procedure as it would then become unnecessary to make up to volume and take only an aliquot for the final operations.

11 Stross, W., *Metallurgia*, 1945, **32**, 257.

TABLE I.—RECOVERY OF KNOWN QUANTITIES OF CADMIUM ADDED BEFORE THE ELECTROLYSIS TO VARIOUS CADMIUM FREE STANDARD ALLOYS.

Sample	Copper %		Lead %		Cadmium %	
	Found	Expected*	Found†	Expected*	Added	Found
High purity Al ..	4·99	5·00	0	0	0·201	0·200
" " " ..	4·94	5·00	0	0	2·00	1·95
" " " ..	5·01	5·00	0·86	1·00	2·00	2·00
British Standard § Aluminium Alloy "A"	4·71	4·68	1·64	1·55	0·01	0·01
" "	4·67	4·68	1·60	1·55	0·201	0·200
" "	4·63	4·68	1·59	1·55	5·00	5·02
ALAR‡ Standard D.T.D.324	1·01	1·01	0·035	0·03	0·013	0·01
"	0·98	1·01	0·03	0·03	0·20	0·20
ALAR Standard " Y " Alloy	4·10	4·10	0·05	0·04	0·007	0·01
"	4·06	4·10	not	done	0·198	0·20

* In the case of the pure aluminium the expected values are the amounts of standard solutions added—in the case of the alloys they are the averages of many determinations, carried out in a number of laboratories.
† The theoretical factor was used for calculating PbO_2 to Pb.
‡ ALAR = Association of Light Alloy Refiners, 3, Albemarle St., London, W.1.
§ Suppliers: Bureau of Analysed Samples, Ltd., Middlesborough.

TABLE II.—COMPOSITION OF THE VARIOUS ALLOYS USED FOR THE EXPERIMENTS OF TABLE I. SHOWING THE NON-INTERFERENCE OF A VARIETY OF ALLOYING CONSTITUENTS.

Alloy	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti
British Standard Aluminium Alloy "A"	4·68	1·34	0·39	0·51	Trace	1·85	2·37	1·51	0·95	—
ALAR Std. D.T.D.324	1·01	1·13	11·28	0·54	0·05	1·03	0·07	0·03	0·04	0·06
ALAR Std. "Y" Alloy	4·10	1·60	0·51	0·54	0·02	2·10	0·06	0·04	0·04	0·14

Wash the electrodes with the usual precautions and transfer the electrolyte to a 200-ml. volumetric flask, cool, make up to the mark and mix.

Pipette 20 ml. of this solution into a volumetric flask or test tube, calibrated at 25 ml. Add 0·1 ml. hydroxylamine solution and 1–2 drops of the thymol blue indicator. Adjust the reaction by adding sodium carbonate solution dropwise until the purple colour changes to yellow. Stir thoroughly after each drop so that the precipitate redissolves. Immerse in boiling water for 5–10 minutes. Cool, add 1 ml. of the gelatine solution, make up to the mark and mix.

De-aerate this solution (or a part of it) by passing hydrogen or nitrogen and record the polarogram, applying to the main potentiometer circuit only half of the usual potential.[12] Begin the recording at approximately − 0·4 volt. (If only half the normal potential is applied the scale shows of course − 0·8 volt). The step is well defined.

Calibration and Non-Interference of Other Metals

For calibrating and for checking the completeness of recovery, use was made of a variety of standard alloys known by spectrographic tests to be cadmium free.

Several samples of each of these were carried through the above procedure side by side. To one of these no cadmium was added; to further samples various quantities of cadmium standard solution were added *before* the electrolysis, and to further samples the same quantities were added *after* the electrolysis.

The type of alloy had no influence on the result and the cadmium waves were identical (within the limits of

12 *i.e.* with the Tinsley ink recording polarograph (Tinsley (Industrial Instruments) Ltd., North Circular Road, West Twyford, London, N.W.10) with which these experiments were made, use one accumulator only.

experimental error), irrespective of whether the cadmium had been added before or after electrolysis ; the " blank," as expected, did not show any wave at all at the half-wave-potential of cadmium.

Table I shows a few typical experiments, Table II the composition of the alloys used. Identical results were obtained on alloys with contents of zinc, copper and magnesium up to 10% (D.T.D.300, L.A.C.10, L.A.C. 113B).

Furthermore, quantities up to several per cent. of various other elements, some of them not normally to be expected in aluminium alloys, were added, alone and in combination, to high purity aluminium and to various alloys. Some were added as the metal, others as the salt, others in the form of " hardener " alloys. They included Ag, Bi, Cb, Co, Cr, Fe, Mn, Ni, Sn, Sb, Ti, Zr. None interfered with the cadmium determination, but some were, as was to be expected, co-deposited during electrolysis.

The *range of cadmium contents* so far investigated was 0·01 to 5%. On the Tinsley instrument the sensitivity 1 (at which 1 microamp produces an excursion of the pen over the full width of the paper) is suitable for approximately 0·05 to 0·2%, sensitivity 10 for up to 2%.

These ranges can probably be extended in either direction. From a few experiments it seems that 4 g. samples can be taken, using 30 ml. of 8N NaOH and 100 ml. of the dilute nitric acid, otherwise adhering to the described volumes and quantities. Higher sensitivities of the polarograph can also be used.

Notes

(1) During the electrolysis the *addition of* a number of *depolarizers* was tried, including urea, hydroxylamine, hydrazine, hydrogen peroxide, potassium chlorate[13] and sodium azide.

It seemed from a number of somewhat inconclusive experiments that the completeness of deposition was slightly improved by the depolarizers, but some of them, (particularly urea, in quantities exceeding a few centigrams, and hydroxylamine) influenced the cadmium wave very unfavourably. For the main purpose of these experiments, i.e. the polarographic determination of cadmium, the copper was sufficiently completely deposited[14] without depolarizers. and their use was therefore discontinued.

(2) The *heating after the addition of the hydroxylamine* is not essential. In some cases the shape of the wave is a little better after heating, in others without heating, but the difference is only slight. No explanation could be found in the composition of the alloy for these differences in behaviour.

Solutions which were not heated sometimes required more counter current than usual, probably in consequence of incomplete reduction of the iron. No direct dependence upon the quantity of iron present was apparent. In view of this it was decided, for the sake of uniformity of procedure, to heat the solutions as described.

(3) At the controlled *p*H and in presence of nitric acid, the *sulphate ion* does not appear to have the unfavourable effect on the polarogram of cadmium reported by J. J. Lingane.[15]

(4) The *silver wire anode* described by J. J. Lingane[16] was used throughout in these experiments for recording the polarograms.

(5) It seems obvious that the electrolysis can be omitted with alloys containing copper and lead. and similar interfering elements, in quantities which are small in proportion to the cadmium content.

Acknowledgment

The author wishes to thank the Directors of the Company in whose Laboratories these experiments were carried out, for permission to publish this paper.

13 Epha, H., *Z. Anal. Chem.*, 1943, **123**, 241.

14 See also Cohen, reference 9, p. 79.

15 *Ind. Eng. Chem., Anal. Ed.*, 1943, **15**, 587.

16 *Ibid.*, 1944, **16**, 329.

Powder Testing Method Standard

Recent developments in the powder metallurgy technique have brought out the importance of measuring powder particles too small to be trapped in sieves. A new Standard establishing a method for the particle size analysis and fractionation of granular metal powders in the subsieve range (1 to 40 microns) using air or gas classification has just been released by the Metal Powder Association. Designated 12–51T "Tentative Method for Subsieve Analysis of Granular Metal Powders by Air Classification," the Standard provides a theoretical background of the air or gas elutriation method based on Stoke's Law along with operational details and drawings of typical classification equipment suitable for subsieve particle size analysis.

At the same time, the Association released another new Standard describing a testing procedure for determining the as-sintered bending strength (modulus of rupture) where applicable, green density, sintering shrinkage and expansion and the as-sintered hardness of compacted and sintered metal powder specimens. Designated 13–51T "Tentative Method for Determination of Bending Strength, Green Density, Hardness and Shrinkage of compacted, Sintered Metal Powder Specimens," this Standard gives working details of the die and punches for making the test specimen as well as details of the fixture for testing bending strength.

Copies of each Standard may be obtained for 25c. per copy from the Metal Powder Association, 420, Lexington Ave., New York 17, N.Y.

New Range of Variable Transformers

Built on the auto-transformer principle, Philips variable transformers are now made in 10 different types, varying in output from 130 VA to 2080 VA. Those of 130–520 VA output are housed in " Philite " casings, whilst the heavier types with upwards of 1040 VA outputs have metal casings. The bench types have a safety fuse fitted in the brush lead, but those intended to be built into an existing installation are not so protected, as it may be assumed the apparatus is already safeguarded in some other way.

The graduated scale and knob permit accurate regulation, to a fraction of a volt, from zero to 20% above the normal primary voltage, whilst the low voltage loss ensures constant regulation. The secondary current on the 220-volt models is limited to 0·5 amp. for the 130 VA models and to 8 amp. for the 2080 VA model.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

A Note on the Measurement of Stress Relief

by C. R. Tottle, M.Met., A.I.M.*

A creep testing machine has been adapted for the measurement of stress relief during a heat treatment cycle, enabling stress, extension and temperature to be plotted against time on the same graph. Correction for thermal expansion is made by a pre-calibration under a small load of 0·05 tons, and adjustment of the straining gear during the actual experiment according to this calibration. A high duty grey cast iron, an ordinary grey cast iron, a cast steel of 0·25% carbon, and a 66/34 cast brass were used to illustrate the principle. The curves obtained were all similar, the rate of deformation being the chief variable. Stress relief occurs rapidly as temperature rises and is well advanced when the maximum is reached. Little advantage appeared to be gained by continuation of heat-treatment after the maximum temperature was achieved throughout the assembly.

In a previous paper[1] the author illustrated several aspects of plastic flow in cast irons, at room and elevated temperature. The methods used were based on those of previous workers mentioned in the bibliography, and determine only the stresses or strains remaining after heat-treatment cycles. It has often been stated that instantaneous recording of stress during a stress-relief heat-treatment would be desirable, but the author has been unable to find any reference to such experiments in the literature.

The present work endeavoured to provide this information, based on the mechanism of stress relief, i.e. a creep phenomenon. The process involved is simple, in that a high stress may be present at room temperature and remain so, only when the rate of plastic deformation (creep) is extremely low. A rise in temperature has the immediate effect of increasing this rate of flow, and at the same time reducing the stress level. The two main factors are therefore the temperature, which controls the rate of flow at a given stress, and the stress itself, which decreases as the deformation proceeds. An ordinary creep testing machine is normally used to measure rates of deformation at constant load, and in special cases, at constant stress. It is therefore necessary, in routine creep testing, to preserve the constant load by using the straining gear to compensate for the deformation which results. If the procedure is varied, by balancing the load as creep takes place, it is possible to determine the stress at any time, which is applicable to stress-relief experiments.

Since a rise in temperature produces thermal expansion of the test piece and that portion of the straining gear within the furnace influence, a correction has to be applied, as otherwise the expansion would be manifest as deformation, and hence a drop in stress. The temperature gradient existing from the uniform temperature zone of a creep furnace to those parts of the machine at room temperature, is considerable, and varies with rise in temperature, hence a calculated correction is inaccurate, and direct calibration becomes essential. By such compensations, the method can be accurate and reliable, and provides a record not only of the relief of stress, but also of the deformation which accompanies it, and the effect of time once a steady temperature has been reached. A single experiment then covers the same range as several experiments at constant temperature but with varying times by methods previously adopted. Since simple tensile loading is used, the load is known accurately, whereas the method of transverse bending does not always allow of such sensitivity. After the experimental procedure had been proved on cast irons, it was thought to be of interest to include brass and steel in the cast state as a comparison, and the present paper includes only four results as indicative of the possibilities.

Experimental Method

The machines used were normal five-ton-capacity creep testing units with test pieces of 0·25 square inches cross sectional area, and temperature control and recording gear assembled as described in a recent paper on creep of cast iron.[2] An accurate potentiometer and Chromel/Alumel thermocouple, (the latter fixed to the centre of the gauge length) was used to record the temperature of the test piece, in addition to the multipoint recorder. The deformation was measured by the normal extensometer where creep was concerned, but with a clock gauge registering on the machine beam for coarser movements. The clock gauge was so fixed that 1 division represented a movement of 5×10^{-5} in. on the 5 in. gauge length of the specimen. A simple stop clock was employed for time intervals in recording, 5 minutes being the standard adopted, unless movement became too rapid, when some measurements were made every 2½ minutes.

Calibration

The machine was loaded on assembly to its lowest scale reading, 0·05 tons, so that the beam was balanced, and the slight tension served to hold the test piece and the grips in one axis. It was not expected that this load would give rise to any creep during calibration, but in order to allow for this, all loads used in actual stress relief measurements were increased by 0·05 tons.

For calibration, the furnace was switched on, using control of the heating rate to correspond as closely as possible to an industrial heating cycle. The clock gauge was zeroed, and the extensometer ignored for this procedure. At five minute intervals, the temperature of the specimen was recorded, the clock gauge reading taken and, immediately, the straining head was adjusted to restore the beam to balance, i.e. the clock gauge to zero. By this means, the thermal expansion of test piece and straining gear involved in the heating, was obtained in terms of deflection of the machine beam, and hence as a suitable correction during the experiment proper. The test was continued up to the maximum temperature required, and for such time afterwards as was found

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1 Tottle. *Proceedings of the Institute of British Foundrymen*, 1947–8, XLI.

2 Tottle. *Ibid.*, 1949–50. XLIII.

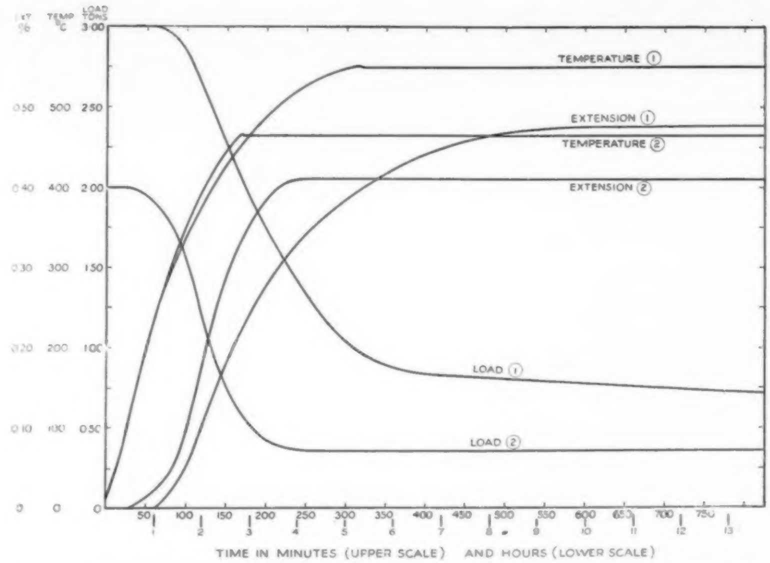

Fig. 1.—Stress relief of high duty grey cast iron (1) and ordinary grey cast iron (2).

temperature was achieved, after which the readings were continued with time as the only variable. The time involved at each recording interval, in taking temperature, clock gauge, adjusting straining gear and finally beam movement, was not greater than 15 seconds, and the error involved in that time is therefore negligible. In certain cases the clock gauge reading was outside its range in 5 minutes, and hence half this period had to be used for readings at those points. (The extensometer readings were taken at the same time as those on the clock gauge, and always agreed with the latter).

By plotting temperature, deformation and stress (as load per unit of original area) against time, a full record of the stress relief cycle was obtained, including the effect of time at constant temperature.

necessary to stabilise the reading—usually about 20 minutes.

Stress-relief Cycle

Following calibration, each test piece was then cooled down to room temperature, and a load applied which corresponded in actual practice to the problem associated with that particular material. (An extra 0·05 tons was added to the load as explained above). A period of 24 hours was then allowed to elapse in order that the clock gauge reading could be checked for any creep at room temperature. Where this occurred, the beam was rebalanced by the straining gear before test. The temperature was now raised again at the same rate as for calibration, and this proved extremely simple, since the assembly remained undisturbed from the original calibration, and was housed in a room of constant atmospheric temperature. Readings of temperature and clock gauge were again made at 5 minute intervals, but from the calibration, a portion of the extension was due to thermal expansion. This portion, read off from the correction graph, was compensated by turning the straining gear until the clock gauge reading had decreased by that amount of expansion proportionate to the particular rise in temperature. The remaining extension was due to deformation only, and was recorded as such. The beam was then rebalanced by running back the counterpoise, and the new load read off from the scale. From each set of readings, therefore, the rise in temperature over the last time interval, the extension due to creep, and the decrease in load which corresponded to that creep, were obtained. The procedure continued in this manner until the set maximum

Discussion of Results

An ordinary grey cast iron, a high duty alloy cast iron, a cast 66/34 brass, and a cast 0·25% plain carbon steel were used to establish the method. The chemical analysis of the four materials is given in Table I, together with the room temperature tensile strength.

The loads adopted in stress relief were assumed to be a reasonable proportion of the maximum stress which might be expected in practice, and the temperatures chosen for the heat-treatment cycle were also judged to be within the accepted commercial range for each material.

Fig. 1 shows the results obtained for the two cast irons, Fig. 2 for the cast brass and steel. The main feature from each graph, is the low temperature at which

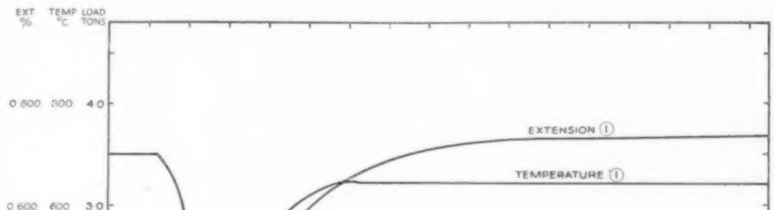

Fig. 2.—Stress relief of 0·25% C cast steel (1) and 66/34 cast brass (2).

TABLE I.—MATERIALS USED IN STRESS RELIEF TESTS.

Material	Total Carbon %	Silicon %	Manganese %	Sulphur %	Phosphorus %	Copper %	Chromium %	Zinc %	Room Temperature Tensile, tons/sq. in.
High-Duty Grey Cast Iron	2·85	1·25	0·95	0·12	0·07	1·2	0·75	—	23·5
Ordinary Grey Cast Iron	3·45	1·92	0·41	0·15	0·14	—	—	—	15·8
Cast Steel	0·25	0·14	0·65	0·07	0·05	—	—	—	31·6
Cast Brass	—	—	0·21	—	—	65·7	Nickel 0·85	33·1	14·1

stress relief becomes measurable, which confirms the trend of the author's previous work on creep at room temperature. The high duty iron (Fig. 1) and the steel (Fig. 2) do not drop in stress until the temperature exceeds 200° C., but no doubt this limit would be decreased if the rate of heating were reduced. All the curves are of similar shape, i.e. a gradual increase in the rate of creep to a maximum, followed by a decreasing rate as the maximum temperature is approached. So rapid is the maximum rate of flow achieved that, in the ferrous alloys, more than 50% of the stress has disappeared before the rate shows appreciable decrease. The brass is more sluggish however, and has not relaxed 50% of the original stress on reaching the maximum temperature. The high duty iron and cast steel continue to creep for some time after reaching constant temperature, though at a small rate, but the ordinary iron and the brass do not show this to any marked degree.

It is obvious from the curves of the ferrous alloys, that little purpose is served in continuing a stress relief treatment much beyond the point at which a constant temperature, uniform throughout the mass, is achieved, though it is important with a cast brass.

The change in slope in the results for cast steel illustrates the sensitivity of the method. The flow is increasing in rate until, at a temperature of approximately 350° C., it suddenly decreases, and then again slightly increases to a reasonably constant rate, finally falling off in a similar way to that for cast irons. The extension curve illustrates this point even more clearly, and it is presumed that the effect is due to the change in strain-hardening capacity of the steel in the so-called " blue-brittle " range.

Conclusions

Using a creep testing machine to measure the relief of stress with time and elevated temperature during a heat-treatment cycle, the rate of deformation can be followed, and the effect of time at the maximum temperature studied. Four materials, two cast irons, a cast steel and cast brass, showed a similar shaped curve of load against time. General conclusions from the curves are as follows :—

1. The relief of stress commences at comparatively low temperatures, and increases in rate to a maximum, in general.
2. After reaching the maximum rate of flow, there is a gradual fall to a constant or decreasing value of stress level.
3. In the three ferrous alloys, over 50% stress relief has resulted before the maximum temperature is reached.
4. The effect of time at the top temperature of the cycle is generally insignificant after the first hour or so.
5. The method is sufficiently sensitive to detect the change in mechanical properties of a steel in the " blue-brittle " range.

Acknowledgment

The work described in this paper was carried out in the Department of Metallurgy, The University of Durham, King's College, Newcastle-upon-Tyne.

Report on Standard Samples for Spectrochemical Analysis (1950)

THIS comprehensive report, which should be of widespread interest and service to all those interested in spectrochemical analysis, analytical chemistry, and allied fields, provides in a form for ready reference current information on spectrochemical standard samples. This latest report, compiled by Sub-committee IV on Standards and Pure Materials of A.S.T.M. Committee E–2 on Emission Spectroscopy, extends and replaces information given in a publication prepared by Messrs. Brode and Scribner, issued by A.S.T.M. in 1944 and revised in 1947. The rapid growth of spectrochemical analysis and a corresponding increase in available standard samples call for a periodic compilation of types and cources of standards for the information of analysts.

Following an introduction describing the scope of the report, with definitions and nomenclature, there are listed in the form of extensive tables and data available standard samples on : iron and steel ; aluminium and its alloys ; magnesium and its alloys ; zinc, lead, and tin alloys ; and copper alloys. Miscellaneous standard samples include : steel-making alloys, ores, and ceramic materials ; semi-quantitative standards ; synthesised mixtures and solutions ; and electrode materials.

The number of standard samples listed in the series of reports are as follows :—

Year	Spectrographic Standards	Chemical Standards	Total
1944	210	103	313
1947	435	113	548
1950	632	120	752

The section on pure materials lists 325 entries supplied by 43 sources. The total number of entries of standard samples and pure substances in this report is 1,077. Various organisations supplying the material are noted.

Copies of this 36-page report (Technical Publication No. 58B)—in heavy paper cover—can be obtained from American Society for Testing Materials, 1,916 Race Street, Philadelphia 3, Pa., at $1.25 each.

Electric Furnace Co., Ltd.

THE Heat Treatment Division of the Electric Furnace Company has now been transferred from Leeds to Wellington Street Extensions, Burton-on-Trent.

The Study of Dusts in Industrial Atmospheres

1—Determination of the Particle Count

By P. F. Holt, B.Sc., Ph.D., D.I.C., F.R.I.C.

University of Reading

There is a growing realisation of the importance of the control of dust in many industrial processes, where its presence can create health hazards and impair the efficiency of operation of the plant. In this series of articles, the principles and capabilities of the several types of apparatus available for the study of dust problems are reviewed and their usefulness in particular investigations indicated.

DUST is one of the most troublesome by-products of industry. Its deleterious effects range from the pathological lesions which are produced in the lungs by certain siliceous dusts to the premature wearing of machine parts due to its abrasive action. Cotton dust may incapacitate machine operators by producing a severe type of asthma. Electrical faults are frequently traced to dust; many of the faults which arise in automatic telephone exchanges are due to this cause although dust is suppressed there by every means possible. Some industrial dusts are of a toxic nature: when breathed they pass through the lungs into the blood stream and act as poisons even more effectively than if the substances were swallowed. In the metal industries, there is an increasing awareness of the importance of dust suppression and this has encouraged the study of operations which may give rise to dust and methods of dust removal.

The complete examination of a dusty atmosphere involves the estimation both of the number of dust particles and the weight of dust in a unit volume of air. Samples large enough for chemical and petrological examination must also be collected. For the determination of particle count (number of dust particles in a cubic centimetre of air) several types of apparatus have been devised. The most accurate estimations are made with the thermal precipitator and this instrument is almost invariably used in fundamental research into dust problems. When a dusty atmosphere is to be examined solely from the aspect of dust control, however, it is usually necessary only to have a means of comparing dust concentrations; the highest accuracy is unnecessary. The konimeter, Owen's jet dust counter and the impinger, are examples of instruments which are much simpler in operation, although less accurate, than the thermal precipitator. These may be used satisfactorily, therefore, in dust control work.

The mass concentration of dust (milligrams of dust in a cubic metre of air) is usually determined either by the salicylic acid filter or the naphthalene filter, both of which instruments were developed by Professor Briscoe and his school at the Royal College of Science, London. Another instrument admirably adapted to dust control work is the Tyndallometer which measures the light which is scattered by suspended dust particles. This instrument can give continuous recordings.

Other apparatus may be required for the collection of samples large enough for chemical and petrological examination. The type of apparatus used for this purpose depends very largely on the nature and concentration of the dust to be investigated. For many dusty atmospheres the salicylic acid filter may be used satisfactorily, but where the dust concentration is very high, as in collieries and cement works, some type of cloth filter will probably be used. Another kind of sampler which will handle some types of dust satisfactorily is the labyrinth, also devised by Briscoe.

It is the intention in this series of articles to review the principles and capabilities of the several types of apparatus used in the study of dust problems and to indicate their usefulness in any particular investigation.

The Determination of the Particle Count of a Dusty Atmosphere

The following instruments will be discussed: (*a*) the thermal precipitator; (*b*) the konimeter; (*c*) the jet dust counter; and (*d*) the cascade impactor.

The Thermal Precipitator

This instrument gives accurate sampling of air-borne dust for microscopic observation. It was originally developed for the Department of Scientific and Industrial Research by Professor R. Whytlaw-Gray and R. Lomax. The design was improved by H. L. Green and H. H. Watson who, at the request of the Medical Research Council, made a study of its efficiency as compared with that of the other types of sampling apparatus.[1] The apparatus makes use of the fact that there is a dust-free space around a hot body, the magnitude of which depends on the temperature difference between the body and the surrounding air. Above the hot body the space tapers off as a cone because of convexion currents (Fig. 1).

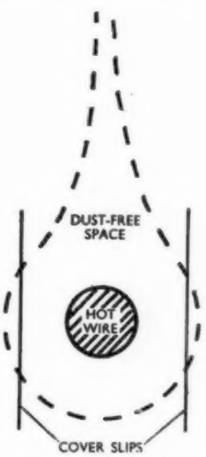

Fig. 1.—Diagram illustrating the dust-free space round a hot body.

The hot body in the thermal precipitator is an electrically heated wire placed between two microscope cover slips in such a position that the space between the wire and the cover slips is entirely within the boundary of the dust-free space. When a

1 Green, H. L., and Watson, H. H., "Physical Methods for the estimation of the dust hazard in industry," Medical Research Council Special Report Series, No. 199 London, H.M.S.O. 1935.

measured volume of air is drawn through this space, by means of an aspirator. the dust which it carries is completely removed and adheres to the cover slips.

Details of the thermal precipitator are shown in the diagram (Fig. 2). The head consists of two brass blocks which are held together by screws. Between them are two thin sheets of bakelite, cut to leave a channel running vertically across the head. A resistance wire is stretched across the centre of the channel and is kept taut by a spring.

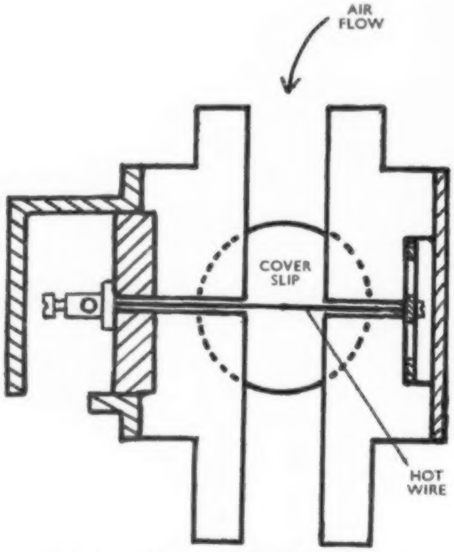

Fig. 2.—Thermal precipitator head.

The microscope cover glasses (No. 1 thickness, ⅞ in. diameter) which are to take the samples are introduced through holes in the brass blocks. They are placed either side of the heating wire on the thin bakelite strips, where they are held by brass plugs kept in position by flat springs. Electrical connection with the heating wire is made at one end to an insulated terminal and at the other to the brass block of the head. Heating is effected by the current from a 2 volt accumulator which is maintained at 1·2 amps. by adjusting a rheostat.

The thermal precipitator head may be mounted on the water aspirator which is used for drawing the air sample through the apparatus (Fig. 3). The aspirator is a hollow brass cylinder of 1,200 ml. capacity, and has an outlet, controlled by a stopcock, from which water can be run out through a fine jet to give a regulated rate of flow of about 6·5 ml. per minute. The volume of water contained in the aspirator vessel is indicated by a gauge and the volume of air drawn through the thermal precipitator is thus determined.

Efficiency of the thermal precipitator. Tests made by Green and Watson have shown that the instrument collects almost 100% of the dust particles in the air sampled. This efficiency holds for particles up to at least 20 microns in diameter and for sampling rates up to 7 ml. per minute. The lower size limit which can be counted is limited by the efficiency of the microscope. Under the oil immersion lens the smallest particles visible are between 0·1 and 0·2 microns in diameter, but by using a special attachment which takes a nitrocellulose film instead of a coverslip, it is possible to obtain thermal precipitator samples for examination under the electron microscope, when the lower size limit is reduced by about ten times.

Fig. 3.—Thermal precipitator head mounted on its aspirator.

The dust samples obtained are in the form of a strip rather less than a centimetre in length across the cover slip which is dry mounted on a slide before the deposit is counted.

Evaluation of the samples. The dust particles are counted under the microscope, usually after heating to burn off organic matter, using a 1/12 in. (2 mm.) objective with oil immersion. Counting is carried out on sample strips 2·2 mm. wide, marked out across the deposit by a special ruled micrometer graticule. Three (for more accurate work five) such fractions, equally spaced along the deposit, are counted. By accurately measuring the length of the deposit with a stage vernier it is then possible to calculate the total number of particles in the whole deposit. Since the heating wire of the thermal precipitator may be unequally spaced between the two coverslips, it is necessary to count the deposits on both coverslips to obtain an accurate estimate of the number of particles in the sampled air. The sizes of the particles in the sample may be determined by reference to calibrated circles marked out at the side of the rulings on the graticule. Size distribution figures for the sample are thus obtained.

Edgar Allen and Co. Limited have secured an order for approximately 1,200 tons of manganese steel castings for lining ball and rod mills at a large copper mine in Chile. As the order originated in New York, some 260,000 U.S. dollars are involved in the transaction. It is intended that a portion of the castings shall be made in the steel foundry of Edgar Allen's subsidiary company in France.

Volumetric Determination of Iron in Aluminium Alloys

By George Norwitz*

A rapid and accurate method is proposed for the volumetric determination of iron in aluminium alloys. The sample is dissolved in hydrochloric acid, zinc pellets are added and the solution filtered. Mercuric chloride is added and air is bubbled through the solution to oxidize the titanium. The iron is then titrated with potassium dichromate in the presence of diphenylamine and phosphoric acid.

PUBLISHED volumetric methods for the determination of iron in aluminium alloys are not entirely satisfactory. The hydrogen sulphide reduction method [2, 4, 6], although accurate, is rather long. Rapid methods that have been suggested [3, 4, 5], give at times erratic results, especially in the presence of titanium [1, 7]. In this paper a volumetric method for the determination of iron in aluminium alloys is proposed which is rapid, accurate and not subject to titanium interference.

Reagents

Potassium Dichromate Solution.—Dissolve 0·43 g. of reagent grade potassium dichromate in water and dilute to 2 litres.

Diphenylamine Indicator.—Dissolve 1 g. of diphenylamine in 100 ml. of sulphuric acid.

Procedure

Transfer a 0·5 g. sample to a 400 ml. beaker and add 20 ml. of hydrochloric acid (1 to 1). As soon as the reaction has ceased, add 2 zinc pellets (large size). Allow the zinc to react for about 2 minutes, while swirling the beaker occasionally. Filter through an 11 cm. Whatman No. 44 filter paper containing 2 zinc pellets. Collect the filtrate in a 250-ml. Erlenmeyer flask. Wash the beaker and filter paper with water. Add 3–4 drops of saturated mercuric chloride solution to the filtrate, and bubble air through the solution for about 3 minutes to oxidize the titanium. Add 3 drops of diphenylamine indicator and 3 ml. of phosphoric acid (85%[8]), and titrate to a dark blue colour which does not disappear on shaking. Deduct a blank. The potassium dichromate solution is standardized by use of a standard sample (National Bureau of Standards sample 86b).

Results

The results obtained for iron in four representative aluminum alloys are shown in Table I.

TABLE I.—RESULTS FOR IRON IN ALUMINIUM ALLOYS.

Sample	Iron Present %	Iron Found %
86b (*a*)	1·53 (*e*)	1·53
		1·53
		1·54
85a (*b*)	0·208 (*e*)	0·21
		0·21
		0·21
195 (*c*)	0·89 (*f*)	0·88
		0·88
43 (*d*)	0·42 (*f*)	0·42
		0·42
		0·41

(*a*) Contains 0·032% Ti.
(*b*) Contains 0·016% Ti, 0·231% Cr.
(*c*) Contains 0·12% Ti, 0·27% Sn.
(*d*) Contains 0·24% Ti, 5·6% Si.
(*e*) National Bureau of Standards certified value.
(*f*) Determined by umpire A.S.T.M. Method (6).

Discussion

The technique of oxidizing titanium by bubbling air through the solution in the presence of mercuric chloride was originated by McNabb and Skolnik[7], but has not previously been applied to aluminium alloys. The amount of titanium normally found in aluminium alloys (under 0·3%) is readily oxidized by bubbling air through the solution for 3 minutes. McNabb and Skolnik[7] recommended bubbling air for a longer period than this. However, these two authors worked with relatively large amounts of titanium. Also, they conducted their experiments with sulphuric acid solutions.

Occasionally a sample is encountered which does not dissolve readily in hydrochloric acid (1 to 1) in the cold. In that case dissolve the sample by warming on the steam bath.

The method is not critical at any stage and several samples may be run at one time.

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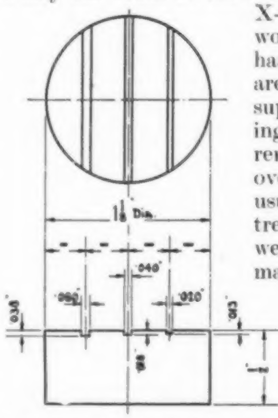
1 Aluminium Co. of America, "Chemical Analysis of Aluminium," p. 18–9, New Kensington, Pa., 1941.
2 *Ibid.*, p. 32–3.
3 *Ibid.*, p. 65.
4 Aluminium Research Institute, "Analytical Methods for Aluminium Alloys," p. 30, Chicago, Ill., 1948.
5 *Ibid.*, p. 33.
6 American Society for Testing Materials, "A.S.T.M. Methods of Chemical Analysis of Metals," p. 146, Philadelphia, Pa., 1946.
7 McNabb, W. M., and Skolnik, H., *Ind. Eng. Chem., Anal. Ed.*, **14**. 711, 1942.
8 Scott, W. W., "Standard Methods of Chemical Analysis," Vol. I, p. 473, New York, D. Van Nostrand Co., 1939.

Preparing Rod Specimens for X-Ray Photography

By D. Summers-Smith, B.Sc., A.R.T.C.*

In preparing powder specimens from reactive metals for X-ray study, difficulty is often encountered, particularly when the filings have to be heat treated before use. If a tiny bar could be cut from the metal and used as the X-ray specimen such troubles would often be avoided, for this has a much smaller surface area than powder and any superficial contamination during the heat treatment can be removed by pickling; moreover, such a specimen could usually be so arranged for heat treatment that only its ends were in contact with refractory material. A bar for this purpose should be about 0·015 in. square and at least ¼ in. long. It is normally difficult to make such a specimen, but using a small jig they are quite easily and safely prepared.



From most materials a bar roughly 0·060 in. square can be cut by hand, using a fine-tooth saw. It is fixed with bitumen into the largest groove of the jig illustrated in the figure, and ground until it is flat with the surface of the jig. The specimen is then transferred to a second groove into which its narrow side fits and it is again ground flat with the jig. A repetition of this process gives a rod of suitable dimensions. For most materials a mild steel jig is suitable, but modifications for special cases are quite obvious.

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